DOCUMENT RESUME

ED 391 638 SE 056 396

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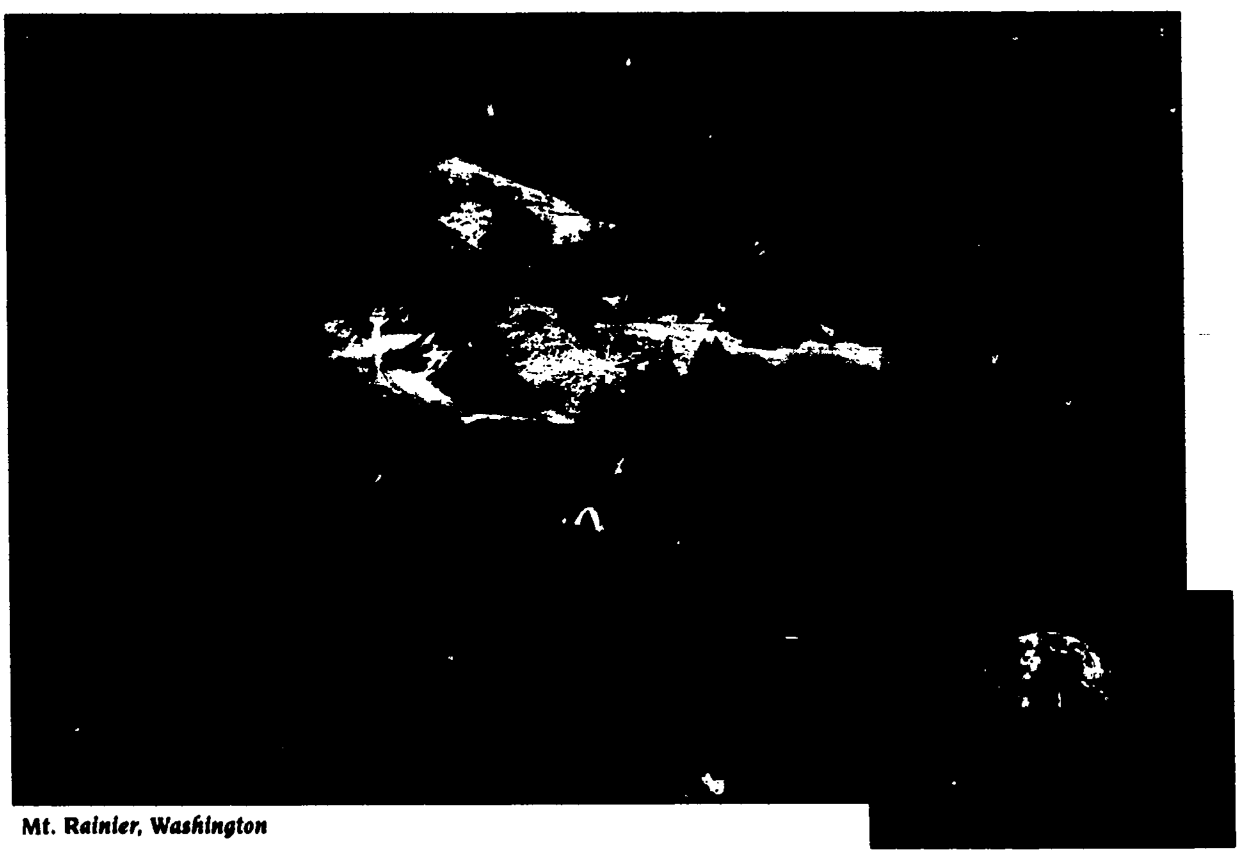
TITLE	Science Is A Study of Earth: A Resource Guide for Science Curriculum Restructure.
INSTITUTION	Ohio State Univ., Columbus. School of Natural Resources.; University of Northern Colorado, Greeley.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	Apr 95
NOTE	252p.; Large poster accompanying original document not included in ERIC copy.
AVAILABLE FROM	The Ohio State University, School of Natural Resources, ECEI Program, 2021 Coffey Road, Columbus, OH 43210.
PUB TYPE	Guides - General (050)
EDRS PRICE	MF01/PC11 Plus Postage.
DESCRIPTORS	*Curriculum Development; Educational Change; *Educational Strategies; Elementary Secondary Education; *Environmental Education; Science Activities; Science and Society; Science Course Improvement Projects; Science Curriculum; Workshops

ABSTRACT

Earth Systems Education (ESE) is an effort to establish within U.S. schools more effective programs designed to increase public understanding of the Earth System that surrounds and sustains us all. ESE focuses on establishing an understanding of the processes that operate within our environment and uses the science thinking and problem-solving processes that are of most use in studying and solving the many social problems that confront the world today. This document is a product of a special summer workshop of participants from the Program for Leadership in Earth Systems Education (PLESE). Sections include: (1) "Exploring Earth Systems Education"; (2) "The National Context for Science Education Reform"; (3) "Successful Strategies for Using Earth Systems Education in Science Curriculum Restructure"; (4) "A Guide to ESE Curriculum Restructure and Implementation"; (5) "Teaching Approaches in an Earth Systems Classroom"; (6) "Resources for Implementing Earth Systems Education"; (7) "Conducting Earth Systems Education Workshops"; (8) "Scoping Out an Earth Systems Curriculum"; and (9) "Sample Activities and Units." (JRH)

SCIENCE IS A STUDY OF EARTH

A Resource Guide for Science Curriculum Restructure



Mt. Rainier, Washington

Earth Systems Education

The Ohio State University • University of Northern Colorado

SCIENCE IS A STUDY OF EARTH

A RESOURCE GUIDE

FOR SCIENCE CURRICULUM RESTRUCTURE

Developed by Staff and Participants of the
Program for Leadership in Earth Systems Education

The Ohio State University
and
The University of Northern Colorado

Victor J. Mayer and Rosanne W. Fortner, Editors

Under a grant from the National Science Foundation,
Division of Teacher Enhancement

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April 1995

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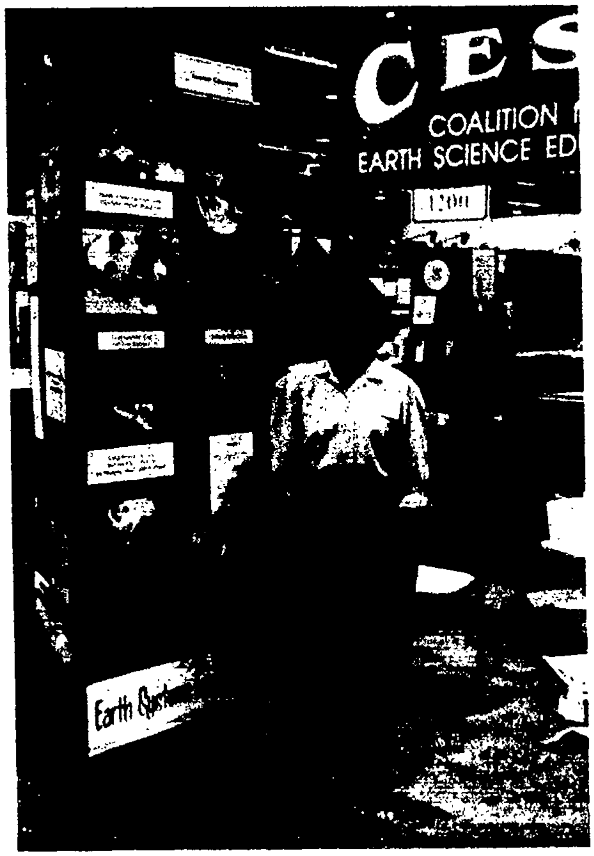
The major contributors to the Project for Leadership in Earth Systems Education (PLESE) and this publication were the 178 elementary, middle school and high school teachers and the 99 school administrators and college representatives on the participant teams. Names and addresses of leaders of the participants teams can be found in Section Four entitled *Resources for Earth Systems Education.*



Rosanne Fortner, Director of the PLESE Eastern Center, at the ESE display, a part of the Coalition for Earth Science Education booth at the 1994 National Science Teachers Association meeting.

*Project Directors and Associate Directors were exofficio members of the Planning Committee and the Futures Committee

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Desktop publishing by Pat Patterson

EARTH SYSTEMS EDUCATION

Preface

Earth Systems Education (ESE) is an effort to establish, within the nation's schools, more effective programs designed to increase public understanding of the Earth System that surrounds and sustains us all. ESE has grown out of the massive effort of science curriculum restructuring that has engaged many scientists and science educators over the past decade. It is a response to the changing needs of a country that has become the only world power—one that is experiencing the environmental and social ills stemming from its focus on a cold war and before that, a succession of World Wars. As our country's situation in the world has changed, so must the science that has assisted it in preparing for wars. ESE is the only wide-scale science education program that is directing its attention to this new world in which the United States and its fellow countries find themselves. It focuses on the subject of all science, planet Earth, placing it at the center of the new science curriculum. Basic science concepts necessary for the understanding of natural processes are taught through a study of the Earth subsystems in which they operate. The concept of "density," for example, can be taught through a study of weather systems and air masses. It is joined again when considering ocean currents and again in looking at the implications of the theory of plate tectonics for explaining earthquakes and volcanic activity. ESE focuses on establishing an understanding of the processes that operate within our environment. It also uses the science thinking and problem solving processes that will be of most use in studying and solving the many social problems that confront the world today. It represents a new definition of science literacy: those aspects of science that are of most importance for our world's citizens. The definition centers on the understanding of the natural processes of our Earth as they are experienced by every citizen, and the scientific procedures through which we have come to understand many of those natural processes.

Earth Systems Education started as an effort to infuse more teaching about the Earth throughout the K–12 science curriculum. A grant from the Teacher Enhancement Division of the National Science Foundation provided support for the Program for Leadership in Earth Systems Education (PLESE) stretching over four years, from 1990 to 1994. During that period of time, about 200 teac[illegible] became directly involved in the program through three-week long workshops conducted at The Oh[illegible] State University and at the University of Northern Colorado. An estimated 7,000 additional teachers have been involved in short workshops conducted by the teacher participants and staff of this effort.

Early in the PLESE program a few participants involved in curriculum restructure in their own districts began to think about creating interdisciplinary science programs using the Earth System as the organizing theme for such programs. They began to emerge in several school systems in Ohio, New York, and Colorado at the elementary, middle school, and high school levels. At the PLESE summer workshop held in Columbus in 1992, a team of teachers developed a strategy for the development of Earth Systems integrated science curricula. They felt that many teachers in school systems throughout the country would be attracted to a vision of a science curriculum that expanded beyond the traditional, cold war emphasis on basic concepts of physics, chemistry, and biology, often unrelated to the Earth systems in which they operate. But they also felt that these teachers needed assistance in developing such curricula. Few of them have the luxury of extra time to think "big"—to design an entirely new approach to their classroom instruction and content. The PLESE planning committee and project staff, therefore, decided to develop a set of resource documents that would assist teachers in developing ESE curricula. An especially selected group of former PLESE participants met in a special summer workshop held in Greeley in 1993. This document is an outgrowth of their efforts.

This resource guide consists of several independent sections. Each can be used separately. There is no linear development of ideas or skills. The sections focus on each of the following themes.

One: The first consists of several articles that have been published about ESE. Its purpose is to provide a knowledge base about the philosophy and approach of Earth Systems Education. Key to this philosophy is the Framework for Earth Systems Education which you will find in its entirety at the end of this first section of the guide. It identifies the important conceptual understandings that lie at the core of ESE. The second foundation that underlies ESE is a collaborative approach to learning. This is discussed in the first article from the *Journal of Geological Education* and again in a special part of Section Five entitled, "Teaching Approaches in an Earth Systems Classroom."

Two: This section includes several parts devoted to a description of the current national climate for science education and the manner in which ESE meshes with projects, such as Project 2061, that have prospered in that national climate. This section can be used by teachers in their attempts to "sell" administrators and the public on these new approaches to science knowledge and learning.

Three: Here we have provided descriptions of several successful efforts by teachers to implement ESE curricula in their schools and school systems. The strategies they have used should provide ideas to the readers on approaches that could be adapted for use in their own situations.

Four: We would anticipate that Section Four is the one that teachers will find of most use. It provides a series of steps and ideas that teachers have found useful in their own efforts at curriculum restructure using the ESE model.

Five: ESE teachers go beyond simply changing the content of their science curricula. They also change their approaches to teaching and assessment. In this section we provide on overview of the type of classroom climate that should typify an ESE classroom. Suggestions are provided on how to conduct collaborative learning and how to use different types of authentic assessment techniques, such as rubrics and portfolios.

Six: Through the PLESE program we learned that there was little need for the development of new teaching materials, at least at the elementary and middle school levels. In this section we provide ideas about sources of materials and information that have been successfully used by teachers in developing ESE curricula.

Seven: If you are serious about developing a modern approach to science curriculum and teaching, you will need to conduct workshops for other teachers to assist them in developing the skills necessary to implement these approaches. In this section we have included teacher developed and tested approaches to conducting short ESE workshops.

Eight: Normally teachers will meet together to develop a syllabus for new curricula. In this section we have included several such syllabi developed for the elementary, middle school, and high school levels. These should provide ideas for the scope and sequence of topics in model Earth Systems Education curricula.

Nine: Here we have included samples of ESE units that have been developed by teachers for the elementary and middle school levels. Also included is an expanded course outline for a high school level, two–year, integrated biological and Earth Systems course. Sample activities are included for each of the sections.

Our intent with this publication is to pass on to other teachers the wisdom of those who have been involved in ESE through PLESE and associated programs. We trust that professional educators at all levels, administrators, supervisors, university curriculum specialists, and science educators, will find in this document the assistance they need to understand the ESE approach and to develop the knowledge and skills needed in implementing it in their own schools.

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Exploring Earth Systems Education

In this first section we have included a series of published articles which the reader can use to develop a background knowledge of the philosophy and history behind Earth Systems Education (ESE). All have been written by individuals involved throughout the development of ESE efforts. Together they represent a history of the development of ESE and an insight into the fundamental philosophy of the program.

Overview of Articles in this Section

The Role of Planet Earth in the New Science Curriculum

This article appeared in the *Journal of Geological Education* and is a record of the emergence of ESE from a concern for more effective teaching about the Earth. It was directed at the Earth Science Education community which represents a well established curriculum interest group here in the United States, unique in the world. The article therefore focuses on the problems of Earth science education as an under represented force in science curriculum decision making and curriculum reform. It is the first published source which suggests that planet Earth might be the logical focus and organizing principle behind a truly integrated science curriculum. As such, it provides a rationale for such a focus. It cites some support for this idea from the writing of Stephen Gould.

What Every 17-year Old Should Know About Planet Earth: The Report of a Conference of Educators and Geoscientists

The second article is the report of a 1988 conference in which the first suggestions for an Earth Systems Education approach to science curriculum and teaching were made. This conference, held to supplement the efforts of Project 2061 of the American Association for the Advancement of Science, included scientists from various federal science agencies and universities, and teachers and science educators from many areas of the United States. Several of the teachers in this conference went on to become essential contributors to the philosophy and structure of Earth Systems Education. The seven Earth Systems Understandings (see the ESE Framework at the end of this section) evolved out of the ten concepts that the conferees concluded were essential components of any science education reform movement. The article, originally published in the journal *Science Education*, will provide the reader with an understanding of the national context in which the ESE concept was formulated and prospered. It also demonstrates the solid, scientific, and practical educational underpinnings of ESE.

The Essential Contributions of Earth Science to Science

There are several contributions of the Earth sciences to science that normally go unnoticed and unrepresented in the science curriculum. Two articles provide a discussion of the three types of contributions; philosophical, methodological, and conceptual. The first article, "Earth–systems science: A planetary perspective" from *The Science Teacher* provides a general overview for practicing teachers of these contributions. It makes a strong case for their inclusion in all science curricula. The second article, "Down to Earth biology", was published in the *American Biology Teacher*. It applies the Earth science contributions in the three domains to secondary school biology courses. It suggests ways in which these unique contributions, such as Deep Time, can be used to enhance biology students' understanding of the Earth they live upon.

Earth Appreciation

This article appeared in *The Science Teacher*. It provides a powerful argument for the inclusion of aesthetic components in science courses. The Earth is beautiful. Its beauty needs to be preserved for future populations to enjoy as our students do. Therefore we must understand its processes and how we influence those processes with population growth and the growth of technology. The article provides examples of how teachers can provide instruction that enhances ESE Understanding #1 (The Earth is unique, a planet of rare beauty and great value) among their students.

Conclusion of Section

This first section of the Resource Guide concludes with two "fact sheets" that can be used by teachers in providing background to parents, school administrators and other teachers of Earth Systems Education and an annotated bibliography of the articles that have been written about this unique science curriculum effort. The first fact sheet is an issue of the ERIC/CSMEE Digest titled **Earth Systems Education**. It provides a brief summary of the development and nature of Earth Systems Education. Following the issue of the Digest, is the most recent version of the **Framework for Earth Systems Education**. It provides the conceptual "check list" for the development of science curriculum.

An Annotated Bibliography of Earth Systems Education Articles

There are other articles that have been published about ESE. You might be interested in doing some further reading. If so, we provide here an annotated list of all such articles published at the time this Resource Guide was completed.

Fortner, R.W. (ed.). 1991. Special Earth Systems Education issue of *Science Activities*. Spring: 28:1.

This issue of *Science Activities* includes the Earth Systems Education Framework and articles with suggestions for teaching toward each of the seven Understandings of the framework. It has won a special journal editors award for excellence.

Fortner, Rosanne W., et al. 1992. Biological and Earth Systems Science. *The Science Teacher* 59(9):32-37.

A description of the Worthington, Ohio, Biological and Earth Systems Science (BESS) course sequence. This is a two-year integrated course at the high school level, replacing the traditional Earth Science and Biology courses for all students.

Fortner, Rosanne W. 1992. Down to Earth biology. *The American Biology Teacher* 54(2):76-79.

A description of the general concepts from the Earth Sciences which, if taught in biology courses, would provide a stronger context and background of biology concepts for high school biology students.

Fortner, Rosanne W. 1991. A Place for EE in the Restructured Science Curriculum. In, Baldwin, J.H. (ed.), *Confronting Environmental Challenges in a Changing World* Troy, OH: North American Association for Environmental Education.

A description of the environmental education goals that can be met by using an Earth Systems focus for the restructuring of the science curriculum.

Mayer, V.J. 1989. Earth appreciation. *The Science Teacher* 56(3)::60-63.

A discussion regarding the place of aesthetics in teaching about planet Earth. Examples are drawn from art, history, and literature that illustrate their use in teaching science.

Mayer, V.J. 1990. Teaching from a global point of view. *The Science Teacher* 57(1)::47-51.

A description of how science can be used as a model for global education. Suggestions are provided as to how science teachers can incorporate global education into their classes.

Mayer, V.J. and R.E. Armstrong. 1990. What every 17-year old should know about planet Earth: The report of a conference of educators and geoscientists. *Science Education* 74:155-165.

Summary of the 1988 conference involving scientists from NASA, NOAA, USGS, and several universities, and science teachers and administrators to determine what every citizen should

understand about planet Earth in order to live "responsible and productive lives in our democracy."

Mayer, V.J. 1991. Earth–systems science: A planetary perspective. *The Science Teacher* 58(1):34-39.
An examination of the philosophical, methodological, and conceptual contributions the study of the Earth sciences can make to the K–12 curriculum.

Mayer, V.J., et al. 1992. The Role of Planet Earth in the New Science Curriculum. *Journal of Geological Education* 40:66-73.
This is a description of the rationale for the use of Earth as a focus for the integration of science programs, K–12. It is directed at the Earth science educational community and therefore documents the frustrations of that community with the general failure to include significant content from the Earth sciences into K–12 curricula, especially at the senior high school level.

Mayer, V.J. 1993. The future of the Geosciences in the Pre–College Curriculum. Paper presented at the International Conference on Geoscience Education and Training (Southampton, England, United Kingdom, April 23, 1993). ED 368 556.
This is an update of the earlier article which appeared in the *Journal of Geological Education*. It provides a much stronger argument for the development of integrated science curricula using Earth as the organizing focus. A version of this ERIC document will be published as an article in *Science Education*.

The PLESE team from the South–Western City Schools (OH) working on a middle school curriculum model.

The Role of Planet Earth in the New Science Curriculum

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ABSTRACT

Earth science is very poorly represented in the nation's science curriculum. The two major science curriculum restructuring projects inadequately present planet Earth in their major understandings. The earth sciences, in turn, have undergone radical changes in the past 20 years resulting in a conceptual shift to what is being called the Earth System. Earth System concepts must be infused throughout the nation's science curriculum. The Earth System, in fact, could very well serve as the conceptual framework upon which to base the entire K-12 science curriculum as the new integrated science curricula evolve. For this to happen, there must be a more accurate understanding of the nature of science among the nation's science-curriculum builders, a better understanding of the naive theories about the Earth System that children bring to the classroom, and adequate resources allocated to the study of science in the nation's schools. Hanging in the balance is a science, political and business leadership, that is earth illiterate, incapable of making the decisions that wi help to insure a habitable planet Earth for our future generations.

Keywords: Earth science – teaching and curriculum; earth science – teacher education; education – precollege; education – science.

Introduction

The science-education community has been confronted with an avalanche of studies and surveys seemingly demonstrating the inadequacy of the nation's science curriculum and how it is delivered. In the face of a veritable storm of concern that has arisen in the wake of these studies, several efforts are now underway to radically change the content and organization of the curriculum. They include "Project 2061" of the American Association for the Advancement of Science (AAAS) and the "Scope, Sequence and Coordination" project of the National Science Teachers Association (NSTA). The "Earth Systems Education" program centered at the Ohio State University and the University of Northern Colorado constitute a related effort. its philosophy and approach to science content is consistent with those of larger and better known national projects, but it differs in significant respects. One major difference is the focus on planet Earth as the connecting subject of the science curriculum. This article describes the rationale for Earth Systems Education, its history and importance, and the implications for research and further development that have proceeded from initial implementation efforts.

Science Literacy

The many studies that have focused concern on our science programs are similar in their sources of information and data. They include attempts at measuring science understanding through paper and pencil tests, or in the case of Jon Miller's studies of adult literacy, telephone interviews. The limitations of such information-gathering procedures for identifying underlying understandings of science processes and procedures are well documented in the science-education literature, especially that dealing with naive theories and misconceptions. Caution should be exercised, therefore, in the ready acceptance of such data as indicative of failures of the science curriculum and teaching methods.

Other types of information that have been cited as indicating deficiencies in our educational system include that relating to our deteriorating position in the world economic community. If such a decline can indeed be linked to failures in our educational system, then there is substantial performance-based evidence of the system's failings. Clearly, however, such measures of educational success must not be uncritically accepted. However one views the data cited in support of science-education deficiencies, there is certainly need for restructuring of a system that hasn't changed appreciably in the last 100 years.

Earth Literacy

Performance-based evidence of a nature similar to that demonstrating our economic decline also occurs in another realm; the prevailing economic and political atmosphere which has resulted in the species-threatening deterioration and resource depletion of our Earth System. If our science curriculum successfully prepares citizens to understand science as a rational attempt to learn about our planet and its environs, we should have Earth-literate physical scientists, engineers, economists, politicians and industrialists who understand the relationships between the processes scientists have identified and engineers have harnessed for economic and defense purposes, and the earth subsystem from which they were derived. Can this be the case when industrialists, encouraged by their chemists and engineers, until recently recommended the continued use of CFCs and the growing and inefficient use of fossil fuels? If our business and political leaders were Earth literate and understood the relationship between species diversity and the well-being of the biosphere with its implications for future human health and long-range economic well-being, would we be destroying the rain forests of the Pacific Northwest for short-range employment, economic, and political benefits? Would our politicians forsake long-range energy policies that would reduce our dependence on oil with its implications for global warming, if not world political and "defense" relationships, if our political leadership

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were Earth literate? Not only are we becoming a science-illiterate country, but even more distressing is the fact that many of our leaders in science, industry, and politics fail to demonstrate by their leadership actions an adequate knowledge of the Earth System. They do not seem to be "Earth literate."

The performance-based type of evidence cited above is supported by the various national and international studies of science achievement and adult scientific literacy. Jon Miller (National Science Board, 1989), for example, found that fully 63 percent of American adults believe that dinosaurs coexisted with early humans. Responding to another question, 65 percent were confused as to the cause of day and night. Fully 54 percent believe that creationism is at least as scientifically credible for explaining the origin of the human species as evolution. That individual physical scientists can be Earth illiterate is illustrated by an article published in *School Science and Mathematics* entitled "On Darwin's Theory of Evolution," in which the writer, a professor of physics, uses typical creationist arguments against evolutionary theory by citing scientists such as Steven J. Gould and Miles Eldredge out-of-context (Aviezer, 1988).

No systematic data on Earth literacy have been collected from our political leaders. However, the following item from *Newsweek* (p. 54, April 9, 1990) is revealing. Vice-President Dan Quayle, who is also chairman of the National Space Council, is quoted in response to the question, "Why send astronauts to Mars?" as follows:

> We have seen pictures where there are canals, we believe, and water. If there's water, that means there's oxygen. If oxygen, that means we can breathe. And therefore, from the information we have right now, Mars clearly offers the best opportunity to see if a man or a woman can be able to survive on that planet.

Our nation's students are equally unprepared to make decisions regarding Earth processes. Understanding of earth-science concepts in the "six nations study," completed by the Educational Testing Service, placed the United States in a last place tie with Ireland with 61 percent of items answered correctly (Lapointe, 1989). The summary of results from the 1984 National Assessment of Educational Progress (NAEP) indicated that, whereas declines in other areas of science achievement of 17 year olds may have been arrested, problems in earth-science knowledge remained:

> Mastery of biology items fell at the same rate as 1977, although the decline is no longer statistically significant. Declines in physical science appear to have leveled off, but Earth-science and integrated topics are areas of concern; declines in both clusters are statistically significant (Hueftle, Rakow and Welch, 1983)

Analysis of the most recent NAEP results found nothing to indicate a turnaround had occurred. In fact performance on earth-science questions dropped another four or five percentage points (Lapointe, 1989).

Misrepresentation of the Nature of Science in Curricula

The history of the development of our science establishment is intimately intertwined with perceived needs for military, defense, and industrial applications. Funding for research, whether from national treasuries or from industrial pockets, has invariably been tied to the demonstration of short-term benefits to the economy, defense, or international status. This approach has had a major impact on the type of science that has been conducted, not only in the United States, but throughout the world. One result has been emphasis upon a deterministic and reductionist paradigm for science, where the isolation and study of specific utilitarian physical or biological processes have been the major goals of investigation. Although the initial observation and description of phenomena have been fundamental in this process, primary emphasis is on the study of phenomena through rigorously controlled experimental techniques. The relatively large amount of political and financial support available to this phase of science has resulted in the historical and descriptive methodologies being ignored and downgraded. They do not produce the economic and military benefits of the "hard" science approach. After all, what practical use is an understanding of the evolution of trilobites or of the development of continents and ocean basins?

The commonly held image of science, therefore, is that of controlled laboratory experiments conducted by a balding white man wearing a white lab coat. Every component of this image is, of course, wrong. The most far-reaching impact of scientific investigation on our intellectual and cultural lives has been the result of investigations using historical and descriptive methodologies. They include among others the heliocentric solar system, the expanding universe, organic evolution, deep time, plate tectonics, and most recently, global climate change.

The science community is now in a state of flux because of the rapidly emerging understanding of the complexity of Earth systems. The "hard" science approach has been unable to provide adequate insight into the complex processes of the Earth systems, illustrating the severe limitations of reductionist science for studying processes as they occur in the real world. Chaos, a mathematical theory born in the 1960s in large part from Edward Lorenz's attempts to produce more accurate weather forecasting models, has seized the mathematical and science communities with what may become the major scientific revolution of our time (Gleick, 1987). It has the power to change how scientists view not only the world in which we live, but how we think about it and how we investigate it.

Chaos theory evolved out of the historical and mathematical sciences, and until recently at least, has been resisted by many of those committed to the traditional deterministic and reductionist approaches used in the physical sciences. We see in this development and growing acceptance of chaos theory, the closing of a circle by the "hard" scientists. The linear approaches to science they have championed originally evolved out of the matrix of the natural sciences. Now with their return to the non-linear, real world of the natural scientists, they bring the mathematical tools that can assist in providing a deeper understanding of our Earth Systems.

Little of the excitement of science enters our classrooms, and little of its fascinating complexity as illustrated by chaos theory, earthquake or weather prediction, or the historical development of continents is afforded our brightest students. Instead, the nature of science continues to be inaccurately portrayed in every classroom in our country. Elementary-, middle-, and high-school students learn that unless a person does experiments she/he is not a scientist. Steven Gould commented on this deep-seated bias against the historical sciences in his article, *Evolution and the Triumph of Homology, or Why History Matters:*

> Historical science is still widely misunderstood, underappreciated, or denigrated. Most children first meet science in their formal education by learning about a powerful mode of reasoning called *"the scientific method."* Beyond a few platitudes about objectivity and willingness to change one's mind, students learn a restricted stereotype about observation, simplification to tease apart controlling variables, crucial experiment, and prediction with repetition as a test. These classic "billiard ball" modes of simple physical systems grant no uniqueness to time and

object – indeed, they remove any special character as a confusing variable – lest repeatability under common conditions be compromised. Thus, when students later confront history, where complex events occur but once in detailed glory, they can only conclude that such a subject must be less than science. And when they approach taxonomic diversity, or phylogenetic history, or biogeography – where experiment and repetition have limited application to systems in toto – they can only conclude that something beneath science, something merely "descriptive," lies before them (Gould, 1986).

The misrepresentation of science that pervades the science curriculum bears bitter fruit in the misunderstanding rampant among the American public of basic concepts such as evolution. The lack of understanding among political and business leadership when confronted by issues such as acid rain, global warming, or deforestation is truly appalling. An understanding of these issues is dependent upon the historical or descriptive methodology of science. An example of this lack of understanding of the descriptive and historical sciences occurred recently when the President's Chief of Staff began to question the mounting evidence for global warming. John Sununu, trained as an engineer, called into question the quality of that data by classifying scientists working on global change with the pejorative label (in his mind) of "environmentalists," and declared his intent to develop his own global-change model. Thus, presumably, using the so-called "hard" or linear sciences to "prove" the "environmentalists" wrong.

Science Curriculum Ignores Planet Earth

We have inherited an ancient and irrelevant high-school science curriculum. Its influence has permeated the earlier grades, negatively affecting the middle-school curriculum, which needs to prepare students for high school, and the elementary-school science curriculum, which of course, needs to prepare students for the middle school. Originally established by the Committee of Ten of the National Education Association in 1893 as the college preparatory curriculum in science, the so called "layer cake" of physical geography, biology, chemistry, and physics, has over the past 100 years changed in only one respect – the effective elimination of the one layer that dealt in some respect holistically with the Earth System – physical geography. Despite the curriculum renewal efforts of the 1960s, the essence of the science curriculum today is little different than that established by the Committee of Ten in 1893. It is the semblance of what science was in the latter 19th century, with a thick, almost impenetrable, overlay of modern facts and definitions that is not at all appropriate for the economic, global, and environmental challenges facing our citizenry today and in the near future.

Is it any wonder therefore that our students and citizens are ignorant of the planet on which they live? Iris Weiss (1987), in her longitudinal studies of science teaching, has documented some of the problems with K-12 science education. She found that only 15 percent of elementary teachers were comfortable with their knowledge of earth science, while 27 percent were comfortable in life science, and 67 percent in mathematics. This is understandable because the Weiss data also indicates that only 44 percent had completed one or more college courses in earth science, while 72 percent had completed a course in physical science and 86 percent in life sciences. Most elementary teachers will emphasize those topics they understand. Therefore little is taught in elementary school about the Earth System or our relationships within it and responsibilities toward it.

At the middle-school level the situation is somewhat better. About 70 percent of our children have the opportunity of taking an earth-science course during one of the three junior high-school years. Most of the remainder will take general science which normally includes some earth-science content. The quality of the earth science taught in junior-high school comes into question, however, when one examines the preparation of the teachers of these courses. Sixty-three percent have had three or fewer courses in the earth sciences, whereas only 15 percent have had three or fewer courses in the physical sciences. Of the three science-content areas, junior-high teachers are by far most poorly prepared in the earth sciences.

The most serious problem, however, is in the senior high school. According to Weiss's (1987) less than three percent of the nation's senior high-school students have the opportunity of taking a course in one of the earth sciences. This might not be a problem, if the concepts of the earth sciences were covered in the traditional physical-science courses, chemistry and physics. This would seem reasonable since earth science is often lumped in with the physical sciences. A recent analysis of the most-used textbooks in those subjects, however, revealed that, for example, *Chemistry*, a widely used high-school chemistry textbook published by Heath (1987), had less than 25 pages of a total of 670, devoted in some way to the discussion of the Earth System. Chapters 1 and 2, which dealt with water and energy, did not contain a single substantive reference to an Earth subsystem. *Physics*, a widely used high-school physics text published by Merrill (1986), had only five pages of a total of 549 which dealt somehow with an Earth subsystem. *Conceptual Physics*, published by Addison Wesley (1987), did much better, but still only 26 pages of a total of 622 dealt with the Earth System. If the topics are not covered in the textbook, then they are most likely not being covered in the courses in physics and chemistry. Weiss' (1987) data indicate that 93 percent of all high-school science classes use a standard published textbook. The 1986 NAEP data (Horizon Research, Inc, 1989) indicate that, in the 11th grade, 70 percent of the students reported reading the textbook in class at least once a week, with 28 percent reporting reading the book every day in class. When asked if they ever read articles about science in class, 39 percent said never, and 26 percent said less than once a week. The most frequently reported classroom activity was "solving science problems." Seventy-two percent reported doing this at least once a week with 30 percent reporting doing it every day. This is probably "doing the problems at the end of the chapter." Thus the available data strongly suggest that, at the senior high-school level, the textbook *is* the curriculum, reinforcing the belief that little is done at that level to acquaint science students with Earth-System concepts and processes. Our future scientists, politicians, economists and business leaders do not have an opportunity, therefore, to take a science course offered at the level of sophistication appropriate for bright high-school students that would inform them about the planet on which they live.

Earth Systems Education: A Movement Toward Solution

Since the curriculum revisions of the late 1960s, there have been tremendous advances in the understanding of planet Earth from the application of high technology in data gathering by satellites and data processing by supercomputers. As a result, earth scientists are in the process of reinterpreting the relationships among the various subdisciplines and their mode of inquiry. These changes are documented in the "Bretherton report," developed by a committee of scientists representing various government agencies with earth-science research mandates (Earth System Sciences Committee, 1988). This reconceptualization of the processes and goals for study of planet Earth has been termed "Earth

System Science." It provides a conceptual basis for rethinking, not only what should be taught in traditional earth-science courses, but the fabric and organization of the total K-12 science curriculum.

The Earth System is a constantly changing entity. Changes occur on two time scales. One set occurs on a scale of millions of years and is illustrated by processes such as plate tectonics and organic evolution. The other occurs on the time scale of decades and centuries and is illustrated by global warming and acid rain. These latter changes are dramatically influenced by the world's human population, an ever more influential component of the biosphere. An understanding of these short-term global changes is essential for the health of future generations of humans and of the planet as a whole. Therefore, a powerful case can be made for making the Earth System a central organizing theme for future K-12 science-curriculum development. There is another reason as well. Science, after all, is fundamentally our attempt to understand our habitat and how we came to be a part of it – in other words, our attempt to understand our Earth system. Why shouldn't the science curriculum therefore be organized around the subject of science, the Earth system?

Project 2061 is the major attempt thus far in laying the basis for a reconceptualization of the content of the K-12 science curriculum. Its report of Phase I (AAAS, 1989) has heavily influenced the recently completed *California Framework* (Science Curriculum Framework and Criteria Committee, 1990), which is being considered as a possible model of science curriculum by more than 20 state departments of education. Project 2061 has also been adopted by the NSTA's Scope, Sequence, and Coordination effort aimed at restructuring the nation's science curriculum. Phase I of Project 2061 was being developed about the time as the publication of the Bretherton report. None of the scientists working on that report were involved in Project 2061. Little of their thinking about the nature of science and the planet that is its most important subject is contained in *Science for All Americans* nor, consequently, the *California Framework*. In the minds of many, this failure to include a central role for planet Earth is a serious omission from documents that may very well determine the future shape and content of science curriculum in this country.

When it became clear that curriculum restructuring efforts might again ignore planet Earth and focus on the deterministic and reductionist model of science, a conference of geoscientists and educators was organized and took place in Washington, DC in April 1988. The forty scientists and educators, including many scientists from the agencies responsible for the Bretherton Report, met over a period of five days. Through small-group interaction techniques they developed a preliminary framework of four goals (Table 1) and ten concepts (Table 2) from the earth sciences that they felt every citizen should understand (Mayer and Armstrong, 1990). The content of this framework was considered by the Project 2061 staff in the development of their final report. Through the work of the conference participants and subsequent discussions with teachers and earth-science educators at regional and national meetings of the NSTA, a new focus and philosophy for science curriculum, called Earth Systems Education, has emerged.

In Spring of 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to Ohio State University for a "Program for Leadership in Earth Systems Education" (PLESE). The objective of the Program is to infuse more content regarding the modern understanding of planet Earth into the nation's K-12 science curricula. During the four years of the grant, some 60 teams, at least one from each of the 50 states, will be prepared in the philosophy of the program. The teams will then gather curriculum resources and learn to organize and lead workshops. They will infuse Earth-systems concepts into their own curriculum and assist other K-12 teachers in their states to do likewise.

In preparation for this program, the PLESE Planning Committee composed of ten teachers, curriculum specialists and geoscientists, met in Columbus in May 1990 to develop a conceptual framework. Preliminary work included analyzing the Project 2061 report for content relating to Earth systems. This analysis, combined with the results of the April 1988 conference, was submitted to the PLESE Planning Committee. Over a period of five days the Committee then developed a "Framework for Earth Systems Education" consisting of seven understandings (Table 3). These understandings provide a basis for the PLESE teams to construct a curriculum guide for their areas of the country and to select existing

Scientific Thought: Each citizen will be able to understand the nature of scientific inquiry using the historical, descriptive, and experimental processes of the earth sciences.

Knowledge: Each citizen will be able to describe and explain Earth processes and features and anticipate changes in them.

Stewardship: Each citizen will be able to respond in an informed way to environmental and resource issues.

Appreciation: Each citizen will be able to develop an aesthetic appreciation of the earth.

Table 1. Four goals set forth at the geoscientists and educators meeting in Washington DC in April 1988 (from Mayer and Armstrong, 1991).

1. The earth system is a small part of a solar system within the vast universe.
2. The earth system is comprised of the interacting subsystems of water, land, ice, air, and life.
3. The earth's subsystems (water, land, ice, air, and life) are continuously evolving, changing, and interacting through natural processes and cycles.
4. The earth's natural processes take place over periods of time from billions of years to fractions of seconds.
5. Many parts of the earth's subsystems are limited and vulnerable to overuse, misuse, or change resulting from human activity. Examples of such resources are fossil fuels, minerals, fresh water, soils, flora and fauna.
6. The better we understand the subsystems, the better we can manage our resources. Humans use Earth resources such as mineral and water.
7. Human activities, both conscious and inadvertent, impact Earth subsystems.
8. A better understanding of the subsystems stimulates greater aesthetic appreciation.
9. The development of technology has increased and will continue to increase our ability to understand Earth.
10. Earth scientists are people who study the origin, processes, and evolution of Earth's subsystems; they use their specialized understanding to identify resources and estimate the likelihood of future events.

Table 2. Concepts that are a prerequisite for an evolving 21st-century view of planet Earth (from Mayer and Armstrong 1991).

The Role of Planet Earth in the New Science Curriculum

Understanding #1: Earth is unique, a planet of rare beauty and great value.

Understanding #2: Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.

Understanding #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

Understanding #4: The Earth system is composed of the interacting subsystems of water, land, ice, air, and life.

Understanding #5: Planet Earth is more than four billion years old and its subsystems are continually evolving.

Understanding #6: Earth is a small subsystem of a solar system within the vast and ancient universe.

Understanding #7: There are many people with careers that involve study of Earth's origin, processes, and evolution.

Table 3. Framework for Earth System Education consisting of seven understandings developed by PLESE Planning Committee.

materials for implementing Earth-systems Education in their areas. Once prepared, teams conduct Earth Systems Education workshops in their states and locales.

The Earth Systems Education Framework (Mayer, 1991) also has implications for the nation's science curriculum. It departs significantly from Project 2061 and the California Framework in its rationale and its focus. The first understanding (see Table 3) emphasizes the aesthetic values of planet Earth as interpreted in art, music, and literature (Mayer, 1989). It stresses the creativity of the human spirit and shows how that creativity has perceived and represented the planet on which we live; a creativity that is also essential to the proper conduct of science. By focusing on students' feelings toward the Earth Systems and on the way in which they experience and interpret them, students are drawn into a systematic study of their planet, that is, into science. By bringing student attitudes and feelings into the science classroom, science becomes more fully and more accurately a human endeavor, one that involves the total human being in the study of planet Earth and its surroundings. Students are able to draw upon a broad range of talents and interests – both right brain as well as left (Mayer, 1989).

The PLESE Planning Committee intentionally arranged the understandings into a sequence, realizing that when numbers are applied priorities are implied. The first two understandings are considered crucial to those which follow, and they depart most dramatically from current science-curriculum recommendations. Placing them first on the list draws attention to them. A variety of techniques and creative activities which involve learning aesthetic appreciation of the planet (the first understanding of the framework) leads the student naturally into a concern for proper stewardship of its resources (the second understanding of the framework). A developing concern for conserving the economic and aesthetic resources of our planet leads naturally into a desire to understand how the various subsystems function and how we study those subsystems, which are the substance of the next four understandings. The last understanding deals with careers and avocations in science, bringing the focus back once again to the immediate concerns and interests of the student.

Integrating the Science Curriculum

There is a strong movement toward reducing the emphasis upon the distinctions among science disciplines in the ongoing science-curriculum renewal effort. This is clearly the goal of the Project 2061 recommendations, which are most easily interpreted as a call for an integrated science curriculum. It is also a reasonable extension of the philosophy of the NSTA's Scope Sequence and Coordination Project. Integrating the science curriculum has certainly been a long-term goal of the science-education community. Attempts such as the Unified Science movement during the 1960s and early 70s have all but vanished as the teachers involved in the original development and implementation efforts moved on to other efforts or retired. Even the attempts of publishers to produce "integrated" elementary-school science curricula have ended up by presenting unrelated units of earth science, biology, and physical science.

What all of the attempts to integrate the science curriculum in the past have lacked was a conceptual focus. The logical focus for a new integration effort is the "Earth System." In essence, science is a study of planet Earth, our attempt at understanding how we got here and how our habitat works. What could be more natural than developing a K-12 science curriculum using the subject of all science investigations (planet Earth) as the unifying theme? Any physical, chemical, or biological process that citizens must understand to be scientifically literate, can and should be taught in the context from which the particular process was taken for examination: its Earth subsystem. That is the major implication for Earth Systems Education and its impact on the nation's science-curriculum reform efforts.

Earth Systems Implementation Efforts

Several projects are underway to test aspects of Earth Systems Education. The major one is the PLESE program, which works with teams of K-12 teachers from each of the 50 states. Through a three-week-long summer workshop the three-member teams develop a resource guide based upon the Earth Systems Framework. To do this, each state team selects a topic within one of the Earth subsystems. The teams then reassemble into grade-level teams and develop a set of questions for each of the seven understandings that are appropriate for students at their grade level. They do this with reference to a scope and sequence grid having three dimensions: attitude, science methodology, and locale. Each dimension takes into account the appropriate developmental level of the student. Once the questions are identified for each of the grade levels, the teams reassemble into state K-12 teams and refine and modify the questions to assure articulation among grade levels. Then the second phase begins: identifying from existing resources the activities, audio-visual resources, student readings, and teacher resources that can be used to address each of the questions on the evolving guide. What results is a K-12 resource guide for each of the Earth subsystems. Eventually, the guides will be edited and integrated into a single Earth Systems Resource Guide, the final step in the three-year-long project. The immediate purpose of the guide development is to provide teachers with a resource of ideas for infusing Earth-Systems concepts throughout the existing K-12 curriculum.

A second project testing aspects of the Earth Systems Education thrust is the development of an Integrated Biological and Earth Systems (BES) science sequence for a central Ohio high school to replace Earth science at 9th grade and Biology at 10th. The sequence, based on the Earth Systems Framework and philosophy, is organized around basic issues concerned with the Earth System; such as global climate

change and deforestation. Th program incorporates collaborative learning and problem solving techniques as a major instructional strategy. Current technology is also integrated into the courses, including the use of on-line and CD-ROM databases for accessing current scientific data for use in course laboratory instruction.

Issues in the Development and Implementation of Earth Systems Education

There are several sets of issues that will affect the development and implementation of Earth Systems Education in the nation's schools. The first relates to the nature of the content and what students know about Earth-Systems concepts. The second relates to the implementation of any new curriculum into the senior high school, especially one that seeks to integrate the sciences.

An important rationale for including aesthetic appreciation about planet Earth as the first understanding of the Framework (Table 3) is that such a focus would stimulate greater interest among students in studying their habitat. Will a focus on aesthetics facilitate and improve learning about Earth systems? How can a student's feelings about Earth and Earth processes facilitate rather than block the development of understanding of Earth processes? Can science teachers effectively integrate topics from art, literature, and music into their science curricula? What mechanisms can be developed to coordinate instruction between humanities and the science curricula of schools?

How can the historical and descriptive methodology of science be effectively taught? Perhaps one of the reasons it is not a more substantive part of the science curriculum is that by its nature the thought processes involved are more abstract and complex than those used in experimental science. Variables cannot be isolated; therefore there has to be a constant and concurrent consideration of all variables in synthesizing and analyzing information. It is difficult for students to collect the types of data that are used in historical and descriptive studies. How can we engage young students substantively in a "minds-on" study of Earth systems?

Most "hands-on" science curricula use activities in which students collect data from simplified laboratory experiments and try to approximate how a scientist would analyze and extrapolate from that data. At best, it becomes a simulation of what a scientist does. At worst, it misrepresents science and leads to a lack of understanding of the nature of science. With the advent of computer and CD-ROM technology, data banks are now being made available to students that provide real Earth-System data. It is now possible for students to manipulate the same data used by scientists in the same way scientists do. Such utilization of data needs to be developed for use in the science classroom. Once developed such activities need to be evaluated for their potential in improving student understanding of science.

Understanding processes in the Earth Systems requires some feeling for large quantities. How much is a million, whether it is years, miles, or tons? Techniques need to be developed and evaluated that lead to an understanding of such large numbers. Little is done now in schools to establish such understanding. Some teachers have their students count dots printed on sheets of paper, posting them on the walls of the classroom. By the time a million is reached they cover the classroom walls. Are such techniques effective? Are there others that could be used? What is the linkage between comprehension of large numbers and comprehension of theories such as evolution and plate tectonics, which depend upon long periods of time, or understanding our place in the solar system or galaxy, which involve enormous distances?

One of the major thrusts in science-education research is the identification of and strategies for overcoming naive theories of natural processes held by students (Linn, 1987). Most of the effort to date has been in studying basic physical-science concepts, such as mass, acceleration and light, isolated from their Earth systems. Several researchers have looked at astronomical concepts such as the seasons, Earth's shape and the moon's shape. (Sneider and Pulos, 1982; Treagust and Smith, 1987; Brewer, Hendrich and Vosniadou, 1988; Vosniadou and Brewer, 1987; Vosniadou, 1987; Nussbaum and Novak, 1976; Nussbaum, 1979; Klein, 1982; Mali and Howe, 1979; Sadler, 1987; Schoon, 1989). Few have looked at processes and how they operate within an Earth System except for several studies of weather concepts (Piaget, 1972; Zarour, 1976; Bar, 1983, 1987, 1989; Stepans and Kuehn, 1988). Very little has been done to identify misconceptions of processes working within the lithosphere or hydrosphere. For concepts about our Earth system to function effectively as a focus and structure for the science curriculum, there needs to be a major sustained effort at identifying such naive theories about the Earth systems. There are some intriguing possible variations from the studies dealing with basic physical processes that result from the local and regional nature of Earth science processes. Do students living in the shadow of a mountain range have naive theories concerning how mountains are formed? Do the naive theories differ with the type of mountains found in the child's locality? Do they have naive theories about severe storms? Do such ideas differ among children living along the coast where hurricanes occur and those living inland in areas frequented by tornadoes? What strategies are effective in changing naive theories of Earth-System processes?

There are a number of factors that affect the implementation of any thoroughly new science curriculum, especially at the high school level. One of the problems associated with the implementation of the Biological and Earth Systems (BES) curriculum has related to Advanced Placement (AP) courses. Where colleges and universities used to have an indirect influence on the content and nature of the high-school curriculum, that influence has become direct and immediate through the spread of Advanced Placement credit. Parents become concerned that their children will not be able to take as many AP courses if an integrated curriculum, such as the BES mentioned above, is implemented. In addition, there is concern that the new curriculum will not provide the background necessary for successful performance in AP science courses. As more and more school districts implement AP science courses in their attempt to provide "more rigorous" science offerings, their influence in dictating the nature of the science curriculum will become pervasive. Yet there is no body of research data on the effects of AP courses. Do they facilitate students' entry to university preparatory programs for science careers? Do AP students do as well in their first college courses in the particular science discipline as those who have not substituted AP credit for the introductory course? If AP courses have such a pervasive influence on the nature of science taught in our high schools, we must have answers to questions such as these.

In an integrated curriculum, how is the more talented science student encouraged? High schools are beginning to use versions of cooperative teaching methods. Can they be defined so that they are effective in stimulating and encouraging the talented student? The BES curriculum is using collaborative learning approaches and a special elective honors designation that integrates honors work with the non-honors classes. How can such an approach effectively stimulate interest without seeming to be merely extra work for students? How can such honors courses be offered without setting the

honors students apart from the rest of the class in their own attitudes and those of the other students?

An ever growing deterrent to curriculum innovation is the effect of standardized testing. In an effort to upgrade education, most states are implementing some form of state-level testing of students. This in addition to the ever-pervasive SATs and other standardized testing programs discourages efforts to substantially reduce the traditional emphasis upon facts and definitions in the science curriculum. In fact, it has added to the problem. This negative impact of testing on science programs is well documented in the literature. What is the impact of testing on curriculum innovation? Can tests be developed that are able to assess understanding of broad concepts and problem-solving abilities? Despite a great deal of concern and emphasis about these questions over the past decade, little of substance has emerged to guide test development and use.

A variety of other questions have been with us over the years but they become especially important if we are to substantially improve the science curriculum. What is an effective scheduling for science courses? The prevailing pattern today is five 45 to 50 minute periods per week. Should this pattern be changed? If so, how? How can we reduce teacher loads? Most of our foreign competitors, those we are being compared with in the international studies of science education, have teachers who teach 15 classes per week rather than the 25 or more taught by typical American high-school teachers. If we are serious about fundamentally restructuring the science curriculum, American teachers must have time to update curriculum and teaching approaches. They do not have that time now. No wonder teachers simply take the next chapter in the text and use that to guide instruction.

Why has it been so difficult to sustain integrated science curricula implemented in our schools? One of the major problems is the weak science background of our teachers. NSTA certification requirements include a major in one of the disciplines, biology for biology teachers and chemistry or physics for physical-science teachers. In most universities the courses included for the teaching major are the same as those for the major in the discipline. Thus teachers become biologists or chemists or physicists. They do not perceive science as a single discipline. When implementing curriculum in the secondary schools they retain a loyalty to their discipline. They don't feel comfortable teaching concepts they consider to be outside their particular discipline. This is no doubt one of the reasons that so little from Earth systems is taught in chemistry or physics courses.

If the new curriculum-restructuring efforts are to succeed, we will have to restructure the science required in the preparation of science teachers. Efforts need to be directed to the development of a unified set of courses at the university level that would be the common ground for the preparation of high-school science teachers in the discipline of science. In such courses, the Earth system will need to be at least an integral part, if not *the* central theme. To do this, university science faculties will need to rethink their discipline's role in the total fabric of science and the contributions it can make to an integrated science course sequence that will need to constitute the core of the science taken by pre-service teachers. To accommodate these changes in teacher preparation programs, certification requirements for science teachers will have to be changed. Careful thought should be given to development of certification standards for a single science program that will accommodate all secondary-school science teachers and will reinforce the trend toward the teaching of integrated science.

Finally, the issue that underlies all others is how to make available a sufficient resource base to solve the various problems in science education and education generally. We as a nation currently rank 10th out of 15 industrialized nations in the percent of gross national product per capita we spend on K-12 education. Yet our political, industrial, and business leaders are saying that we already have all the money needed for an effective education. How do we refocus the national debate? How can we convince our opinion leaders and our average citizens that additional resources must be made available if we are ever to reach the national objectives for science education stated recently by our governors and the Bush administration?

Conclusion

The time appears to be ripe for the first total restructuring of the science curriculum since the Committee of Ten established the current high-school sequence in the late 1800s. The dramatic changes that have taken place in science and in the understanding of how science is learned, and the evolving demands of technology and the pressures it places on our environment require this restructuring. We must develop a citizenry and a cadre of leaders who are comfortable with science and knowledgeable about the role it plays in understanding our Earth System. They need to understand the applications of science in technology and the role technology plays in our society, in science and in changing our Earth systems. Earth Systems Education offers an effective approach for reaching these objectives. As a first step it provides for infusing planet-Earth concepts into all levels of the K-12 science curriculum. For the long run, it provides an organizing theme for a K-12 integrated science curriculum that could effectively serve the objectives of scientific literacy and, at the same time, provide a basis for the recruitment of talent into science and technology careers, thereby helping to ensure appropriate economic development consistent with maintaining a high-quality environment.

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The authors are all members of the Planning Committee of the Program for Leadership in Earth Systems Education (PLESE), funded by the Teacher Enhancement Program of the National Science Foundation in a grant to the Ohio State University. The ideas and opinions are those of the authors and not those of the National Science Foundation. Mayer is Director of PLESE, Fortner directs the Eastern Center, and Hoyt the Western Center of PLESE. Armstrong, Barrow, Brown, Crowder, Humphris, Jax, Mayer and Shay were also leaders or participants in the Conference of Educators and Geoscientists held in 1988. Although Mayer took the responsibility of writing this article many of its ideas evolved out of the April 1988 Conference of Educators and Geoscientists, the planning conference for PLESE and informal conversations between the various individuals.

What Every 17-Year Old Should Know About Planet Earth: The Report of a Conference of Educators and Geoscientists*

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Introduction

There is great public concern regarding the quality of science curricula in the nation's schools. This concern has resulted in a number of efforts to redefine curriculum and especially to identify the curricular bases for scientific literacy. Perhaps the most prominent of these efforts is that of the American Association for the Advancement of Science, Project 2061 (AAAS, 1989). Such efforts in the past have, in the opinion of some science educators, neglected Planet Earth despite the fact that one could consider the entire domain of science as being an effort to understand our planet and how its processes work. Curriculum efforts, like the science disciplines that sponsor them, have often taken a reductionist approach focusing on the specific contributions of certain scientific disciplines in understanding concepts and processes within their defined domain, failing to relate them to the earth system in which they operate and interact with other processes and concepts. But, whereas scientists have seen the limitations of the traditional science disciplines and have spawned a variety of interdisciplinary efforts to understand basic processes, the science curriculum is trapped in the century old curricular straight-jacket of biology, chemistry and physics. This seems to have insured the neglect of the planet earth systems that are our home and govern our well-being.

To provide a basis for an adequate representation of Planet Earth in the current curriculum efforts, a conference of educators and geoscientists was held in Washington, D.C. in April, 1988. The four and one-half day conference identified those

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Science Education 74(2): 155–165 (1990)

CCC 0036-8326/90/020155-11$04.00

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goals and concepts about Planet Earth that every 17-year-old should know when completing pre-college education. The sponsors of the conference were the American Geological Institute and the National Science Teachers Association. The results of the conference have wide-spread implications for the content of curriculum materials and instruction in K-12 science and geography courses. This article is an adaptation of a report of the conference published by The Ohio State University (Mayer, 1988).

Background

Participants in a meeting of educators and geoscientists held in September, 1985, concluded that the top priority for improving programs in earth science education was the development of a K-12 earth science syllabus. Those attending the meeting, held at the headquarters of the American Geological Institute (AGI) in Alexandria, VA, and supported with a grant from the National Science Foundation (NSF), also concluded that such a document if it bore the endorsement of both the scientific and science education communities would have a strong impact on the content of textbooks, state and local curriculum guides, and state and national tests. Participants felt that it would provide guidance for educators and scientists in conducting cooperative efforts to improve the teaching about Planet Earth in the nation's schools.

In Autumn, 1987, several science educators and science agency representatives in Washington, D.C., after lengthy discussions, concluded that the first step in developing such a syllabus would be to convene a conference of eminent scientists to identify the components of our current knowledge of Planet Earth that have relevance for the K-12 curriculum. Conversations with representatives of the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), and the Directorate of Geosciences for NSF led to agreements to identify and support three or four scientists each to participate in such a conference. The scientists were selected within each agency using four criteria. Any scientist selected should:

1) be recognized by peers as a leader in the discipline.
2) have a broad knowledge of earth systems and be able to see beyond his/her specialty to the broad conceptual fabric of earth systems.
3) have an interest in science education and have a commitment to help improve the science curriculum.
4) be an effective communicator.

Nineteen scientists meeting these criteria participated in the conference.

The conference organizers (see Appendix) felt that scientists by themselves would have a difficult time completing the conference task since few would have any direct experience with schools and science curricula. Thus it was decided to invite about twenty teachers, supervisors and science educators as conference participants. They would bring knowledge of the nature of children and of the teaching task to

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the conference, providing a point of reality that would ensure that the understandings identified by the conference would indeed be those that every 17-year-old could know and understand. The educators were selected on the basis of the quality of their science backgrounds and their records for leadership in their own school systems and nationally. In addition, care was taken to ensure representation geographically, by grade level taught, and by role within the educational establishment. As a result there were elementary, middle school and high school teachers, state level science consultants and university science educators represented among the participants. The educators found their own sources of support for the conference primarily from their school systems and universities. AGI received a grant from the Science and Engineering Education (SEE) Directorate of NSF to cover the administrative and logistic costs.

The conference, therefore, had a national perspective resulting from participation of scientists from three science agencies each with a national mission (NASA, USGS, and NOAA); scientists from universities in Oregon, California, South Carolina, Massachusetts, and Oklahoma; science educators from universities in Minnesota, Missouri, and Ohio; and supervisors and teachers from Washington, Idaho, California, Texas, Michigan, Ohio, North Carolina, Virginia, and New York. Its conclusions, therefore, can indeed represent a national agenda for reforming what is taught about Planet Earth in our nation's schools.

The Conference Charge

It had been over twenty years since the science community had been closely involved with educators in identifying the concepts in the earth science disciplines that should be taught K-12. Because of the technical advances provided during that time in data gathering and processing and the intensive investigations of the earth system, our knowledge of Planet Earth had changed dramatically. The charge to the conference was to identify those understandings about Planet Earth that every citizen needs to know in order to live a responsible and productive life in our democracy.

In attempting to fulfill the charge, the keynote speaker, Dr. F. James Rutherford, Director of Project 2061 of the American Association for the Advancement of Science, cautioned the participants to avoid the usual pitfalls of such efforts. He advised the group to discuss curriculum, not courses; not to buy in to the status quo of the existing curriculum structure but to consider the place of earth concepts in the total purview of science. Identify the concepts or processes that are important for the well being of citizens, not those that might contribute at some later undefined time to the understanding of some equally hazily defined goals. Rutherford is concerned, as are many science educators, that the current science curriculum is "bloated and overstuffed." Students are required to memorize a vast array of trivia, most of which is forgotten soon after the test. He warned the participants not to add to that problem. In deciding on what new concepts to include, participants should also decide what old concepts should be eliminated from the curriculum. This trade-off always needs to be in mind. In addition, the elements identified for inclusion must contribute to the general aims of education.

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Rutherford emphasized the need for curriculum to reflect the current requirements of our social and economic systems and the basic understanding of the nature of scientific investigation. The various science disciplines are now intimately intertwined. Mathematics is the essential tool of modern science. More and more science is applied in industry and defense. Citizens must develop a fuller understanding of how technology is used in our society. They must have a clear understanding of evidence as the real authority in science, of the power of theories in the investigation of nature, of science as a conservative enterprise requiring replication and openness. There needs to be a focus on the unifying themes, such as systems, models, and evolution.

In choosing facts and concepts he warned participants not to fall into the trap of "watering down" ideas from the sophisticated ideas that "all scientists must understand." Instead, identify what is fundamental, then build on that structure. Rutherford suggested several criteria that should be applied in making judgements regarding possible curricular elements:

1. What is the scientific significance? Will the concept or fact still be around in the next generation?
2. What is the human significance of the idea? How does it affect or influence citizens?
3. What is the philosophical power of the idea? How does it contribute to our understanding of the world?
4. What is its current importance to our social and economic well-being?
5. How does it contribute to personal enrichment? Does it make the world of the pre-18-year-old more interesting?

Rutherford concluded with several general suggestions. He invited the earth science education community to join in the total school reform movement. This is one of those times in history when it is possible to reconstruct the educational system. He encouraged all to participate in designing the system of tomorrow. Think K-12, infiltrating the entire curriculum with Planet Earth concepts. Emphasize the concrete, how things work, the dynamics of the earth system. Feature the connections to the other sciences. Make those sciences more interesting to students by showing how they can be applied to Planet Earth problems or concepts. Give priority to ideas and methods rather than words. Beware of authoritarianism, be open to the inclusion of new concepts, ready to discard the old.

Organization

As soon as each scientist was identified he/she was sent a letter requesting the development of a short, three-page paper outlining his/her preliminary ideas regarding what every high school graduate should know about her/his field of inquiry. They were then compiled and sent to each of the participants about one week prior to the beginning of the conference. These papers provided the focus for the first round of discussions. Scientists were assigned to one of four groups based upon

their specialty. An equal number of educators were assigned to the groups such that each scientist was teamed with an educator. Each of the resulting groups of about eight individuals each were led by a facilitator. Each group was to reach consensus on the goals and concepts regarding Planet Earth to be included in the education of every citizen. Each day started with a presentation to the entire group. Rutherford's keynote address was followed on the next day by a talk by Dr. Audrey Champagne from the Office of Science and Technology Education of the AAAS. It focussed on learning problems afforded by misconceptions or naive theories. On the third day, Dr. Dallas Peck, Director of the United States Geological Survey, presented a talk outlining his perception of the place of the earth sciences in the general education of our citizens. The general presentation was followed each day by two small group sessions, one immediately after the talk and the other following the lunch break. Participants were brought together again at the end of the afternoon for two one-half hour presentations by participants on topics of general interest.

At the end of each day the small groups recorded the results of their discussions. These were typed, reproduced and made available for their deliberations the following day. On the third day of the conference, the groups were reassembled such that each of the new groups included an educator-scientist team from each of the previous groups. The charge to three of the groups was to integrate the conclusions from all four groups into a single set of recommendations. This resulted in three versions. On the afternoon of the fourth day of the conference these three versions were integrated by the total group through the use of group dynamics processes, such that consensus was reached on each aspect of the framework that resulted. The fourth group was asked to develop a set of guidelines for the development of a senior high school earth systems course.

On the morning of the fifth day, most of the educators assembled to put the finishing touches on the conclusions of the conference. At this session wordings of the goals and concepts were agreed upon, and a preamble for the conclusions was developed.

Conference Results

Following are the results of the conference. Minor editing has been done to improve reading style, but the substance remains identical to that agreed to by the participants.

Preamble

As the 21st Century dawns, we find ourselves in the midst of a revolution in our knowledge concerning Planet Earth. It is imperative that every 17-year-old develop an understanding of Earth concepts as well as appreciate the beauty of the Planet Earth.

The Earth seen from space is both metaphor and reality of a deepening consciousness of the integrated view of our planet necessary for its successful stew-

ardship. Catalyzed by an accelerating technology, a holistic view incorporating dynamic images and ideas provides incredible opportunities to ignite the imagination of American students.

Our report outlines the goals and concepts that are a prerequisite for an evolving 21st century view of Planet Earth. To imbue this framework with the spirit of revolution intended, educators should recognize the importance of the following issues:

1. Emphasize K-6
2. Demand a hands-on, investigative approach
3. Encourage and include minorities and women throughout the process
4. Integrate the various science disciplines and emphasize geographic ideas
5. Incorporate more mathematics, computers and emerging technologies
6. Develop issue oriented case studies
7. Involve parents and the community
8. Capture the excitement and fun of learning about Planet Earth

Goals

SCIENTIFIC THOUGHT. Each citizen will be able to understand the nature of scientific inquiry using the historical, descriptive and experimental processes of the earth sciences.

KNOWLEDGE. Each citizen will be able to describe and explain earth processes and features and anticipate changes in them.

STEWARDSHIP. Each citizen will be able to respond in an informed way to environmental and resource issues.

APPRECIATION Each citizen will be able to develop an aesthetic appreciation of the earth.

Concepts

1. The earth system is a small part of a solar system within the vast universe.

   The sun is the primary source of Earth's energy.

   The sun is one of the billions of stars in the universe.

   The moon and Earth affect each other.

   All bodies in space (including Earth) are influenced by processes acting throughout the solar system and the universe.

   The nature of each planet is determined by its position in the solar system and by its size.

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The position and motion of Earth with respect to the sun influence tides, seasons, climates, etc.

2. The earth system is comprised of the interacting subsystems of water, land, ice, air and life.

   Water exists as a vapor, liquid and solid and changes form as a result of changes in energy.

   Oceans are in constant motion and are a resource that covers over 70% of the planet.

   The cryosphere (frozen water) is an Earth subsystem that has varying seasonal and global distribution.

   Atmospheric circulation is driven by solar heating and modified by interactions with other subsystems.

   The solid earth (lithosphere, asthenosphere) interacts with the hydrosphere, atmosphere, cryosphere and biosphere.

   The biosphere interacts with other subsystems.

   The sun is a major source of energy that influences the earth system.

   Geothermal energy influences the dynamics of earth systems.

   Each component of the earth system has characteristic properties, structure and composition.

3. The earth's subsystems (water, land, ice, air and life) are continuously evolving, changing and interacting through natural processes and cycles.

   Water cycles through the subsystems.

   The outer layer of the solid earth is composed of plates which are and have been in motion.

   All new rocks are derived from old rocks by recycling.

   Major examples of the interaction between components of the earth system are the hydrologic cycle, rock cycle, carbon cycle, glacial cycle, trophic cycle.

4. The earth's natural processes take place over periods of time from billions of years to fractions of seconds.

   Physical processes in the universe range over time scales of seconds to billions of years and over very great distances.

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Earth is more than 4 billion years old and is continually evolving.

The atmosphere is a thin, protective blanket composed of various gases and other substances that evolve over geologic time.

Fossils are the evidence that the biosphere has evolved interactively with the earth over geologic time.

Evolution results in a sequence of unique historical changes of Earth's subsystems. For example: changes in atmospheric composition, changes in life forms, changes in structure of the solid earth, changes in the composition of the hydrosphere.

Time scales for Earth changes are variable. For example:

Long-term evolution of the solid earth and atmosphere (4.5×10^9 years)
evolution of life (4×10^9 years)
break-up of Pangaea $5(1.8 \times 10^6)$ years
ice ages
extinction of plants and animals
drought
seasons
daily weather
nuclear reactions

Short-term chemical reactions

5. Many parts of the earth's subsystems are limited and vulnerable to overuse, misuse, or change resulting from human activity. Examples of such resources are fossil fuels, minerals, fresh water, soils, flora and fauna.

6. The better we understand the subsystems, the better we can manage our resources. Humans use Earth resources such as minerals and water.

7. Human activities, both conscious and inadvertent, impact Earth subsystems.

Human use/activities influence the:
hydrosphere and vice versa.
cryosphere and vice versa.
atmosphere and vice versa.
lithosphere and vice versa (mining, hazards, etc.)
biosphere and vice versa

Human activities exert inordinate impact on the global environment. Human activities alter Earth's components such as burning fossil fuels, improper land use, war and war preparations, releasing hazardous chemicals and radioactive materials, releasing and disposing hazardous materials, extinction of species.

8. A better understanding of the subsystems stimulates greater aesthetic appreciation.

   Humans appreciate and manage the Earth by preservation, appropriate utilization and restoration. For example: natural parks, reclamation, conservation, recreation, legislation, land managment and planning, international to local cooperation.

9. The development of technology has increased and will continue to increase our ability to understand Earth.

   Technology has improved our ability to understand the earth. For example: optical and electronic microscopes, optical and radiotelescopes, infrared sensing, doppler radar, submersibles, satellites, computers.

10. Earth scientists are people who study the origin, processes, and evolution of Earth's subsystems; they use their specialized understanding to identify resources and estimate the likelihood of future events.

    Observations of the atmosphere are used to forecast weather.

    Maps are scale models of the Earth.

    Knowledge of other planets helps us understand the Earth.

Analysis of Conference Results

On the last day, during the final editing of the conference recommendations, someone asked whether the results were any different than those from similar conferences held twenty years ago. Several of the educators were familiar with the Earth Science Curriculum Project, the last major effort in earth science curriculum renewal. They felt that the differences were dramatic. Content relating to the third goal, stewardship, was hardly considered for inclusion in the ESCP materials. Goal four, aesthetic appreciation of the earth, would not have been thought of as appropriate when considering science curriculum. It is clear that the scientific community has changed in its attitudes and values in the ensuing years.

The results of this conference are consistent with current movements in science curriculum revision that are exemplified by Project 2061. The participants were not only able to think beyond the current goals of science and science teaching, but to go beyond them in a creative and enthusiastic manner. The recommendations reflect the challenge that Rutherford made in his opening talk to not be bound by the past and to think creatively as to what curriculum can be. Thus they in turn challenge the science education community to develop a curriculum that is dramatically different, one that adequately incorporates a modern knowledge of Planet Earth, the manner in which we investigate our home, the implications of technology for our future habitat and an appreciation for the beauty implicit in our earth

systems. Science educators are challenged to incorporate an understanding of students and how they come to investigate the earth into planning future curriculum and teaching.

The Next Steps

This conference represents the first national effort in over twenty years to involve geoscientists in a significant way in the identification of appropriate curriculum content regarding Planet Earth. As such it is a first step. The framework developed by the conference must now be translated for the use of classroom teachers, textbook publishers, test developers and curriculum specialists. This will require the cooperation of many different organizations and individuals in science, science education, and educational policy development and implementation.

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Accepted for publication 26 September 1989

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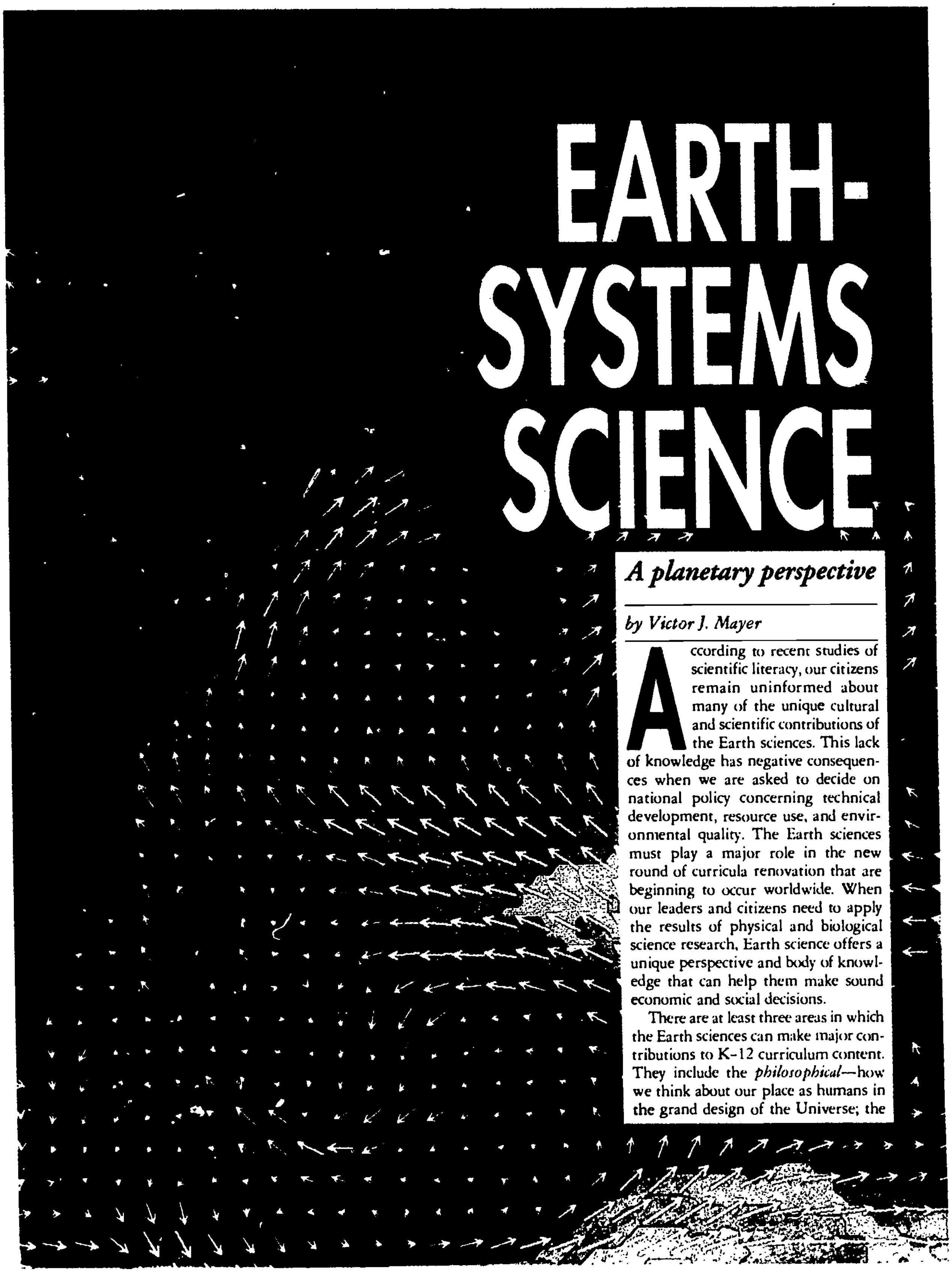


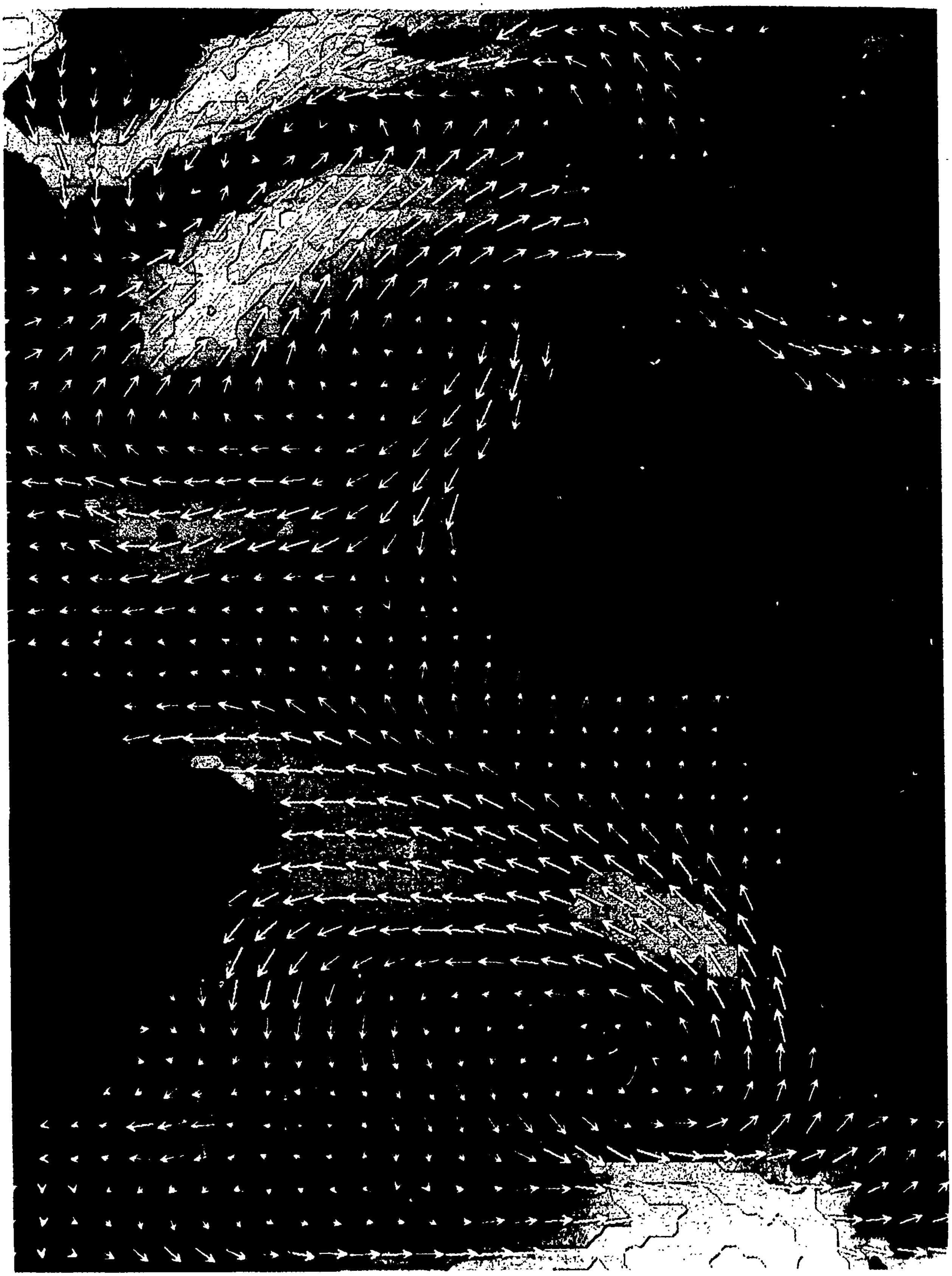
EARTH-SYSTEMS SCIENCE

A planetary perspective

by Victor J. Mayer

According to recent studies of scientific literacy, our citizens remain uninformed about many of the unique cultural and scientific contributions of the Earth sciences. This lack of knowledge has negative consequences when we are asked to decide on national policy concerning technical development, resource use, and environmental quality. The Earth sciences must play a major role in the new round of curricula renovation that are beginning to occur worldwide. When our leaders and citizens need to apply the results of physical and biological science research, Earth science offers a unique perspective and body of knowledge that can help them make sound economic and social decisions.

There are at least three areas in which the Earth sciences can make major contributions to K–12 curriculum content. They include the *philosophical*—how we think about our place as humans in the grand design of the Universe; the



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methodological—the intellectual methods that we use in investigating our surroundings; and the *conceptual*—what we know about our world and how it functions.

PHILOSOPHICAL CONTRIBUTIONS

Before James Hutton's *Theory of the Earth* was published in 1795, our planet was thought to be a mere 6000 years old. Hutton's book introduced the concept of "deep time," and 40 years later Charles Lyell expanded on this concept in *Principles of Geology*. Lyell suggested an Earth of great age, upon which "observable processes" developed the features of rocks and landscapes. This concept became the basis for the development of all modern geological concepts. It also set the stage for Darwin (who, soon after Lyell's book was published, took it on his famous voyage) to develop the theory of organic evolution.

These scientific theories have had a great impact on our culture; we can no longer consider the Earth as having been created specifically for man's use. Stephen Gould, in his recent book, *Time's Arrows, Time's Cycle*, quoted Mark Twain's tongue-in-cheek depiction of this attitude:

"Man has been here 32 000 years. That it took a hundred million years to prepare the world for him is proof that that is what it was done for. I suppose it is, I dunno. If the Eiffel Tower were now representing the world's age, the skin of paint on the pinnacle-knob at its summit would represent man's share of that age; and anybody would perceive that that skin was what the tower was built for. I reckon they would, I dunno."

The current attitude that we can squander Earth's resources and somehow be saved from the consequences is not tenable. We now understand that

we occupy a planet that has evolved over several billions of years. We, ourselves, are a very recent result of a process that has gone on for an equally long period of time and that has resulted in the extinction of many life forms.

The Earth sciences deal with deep time as a fundamental element in their structure. Therefore, they are the place in curricula where an understanding of this concept must be developed. Teaching for a true understanding, however, is extremely difficult. Gould says:

"An abstract, intellectual understanding of deep time comes easily enough—I know how many zeroes to place after the 10 when I mean billions. Getting it into the gut is quite another matter. Deep time is so alien that we can really only comprehend it as metaphor. And so we do in all our pedagogy. We tout the geological mile (with human history occupying the last few inches) or the cosmic calendar (with *Homo sapiens* appearing but a few moments before 'Auld Lang Syne')."

Teaching about deep time, therefore, requires a great deal of thought and creative effort. One problem is developing an understanding for immense numbers such as a million or billion. To put things in perspective, one eighth grade Earth science teacher has the students in each of his classes count dots printed on pieces of paper. When one sheet has been counted it is taped to the wall. By the end of the day, the walls are covered and the cooperative count has reached only one million. Another Earth science teacher has his students use their bodies to construct the geologic time scale. Using a scale of one meter to 10 million years, students place themselves at different events on the time scale. In this way they become intimately involved with both the events and the relative time in which they

occurred. The resulting time scale stretches the entire length of the school building (450 m).

Deep time is just one concept that has helped us understand our place in the Universe. Equally important was Copernicus' restructuring of the solar system into a heliocentric model and the subsequent understanding of the place of the solar system itself within the Galaxy and the Universe. It has become more and more difficult to think of the world as having been created solely for us—to be used as we see fit; it was this attitude that is responsible for the environmental problems we are now facing. The concept of organic evolution has further eclipsed the egocentric philosophy. We are only one branch of a long series of developments that has survived because the previous branches lived in harmony with their environment.

THE METHODOLOGICAL CONTRIBUTIONS

The Earth sciences provide an excellent opportunity for students to learn the problem solving approaches of the scientist. Students can experience weather systems, observe weathering taking place, and interpret landscapes in the vicinity of their homes. Such experiences can entice them into searching out a deeper understanding of the nature of scientific investigation.

Steven Gould, in his address to the 1987 NSTA convention, decried the low status given the methods used by Earth scientists, such as the historical method. The experimental method is held up as the hallmark of science in elementary and secondary science teaching; however, it is the historical and descriptive methods that have given us the truly powerful ideas about ourselves and our place in the Universe. After all, Copernicus did not perform experiments to reorder the solar system with the Sun at its center, nor did Darwin perform experiments to create his theory of evolution.

In reality, there is no one method of science. What marks science as a discipline is the gathering of real-world data and the objective analysis of that data to gain meaning for how the world operates. Conducting experiments is simply one way of obtaining data. They are usually conducted to verify ideas derived from data obtained by observations and descriptions of Earth's processes. But our students believe that the only science is experimentation. They are led to believe that experiments are the only way to experience "hands-on" science. But there are many ways the Earth science teacher can exemplify the historical and descriptive approaches in a "hands-on" mode; for example, by charting changes in a stream over time, or gathering and analyzing weather data.

Deep time is just one concept that has helped us understand our place in the Universe.

The discovery of deep time, the development of the theory of evolution, our understanding of our Universe, and the knowledge we now have of our planet's evolution and its environs are basic concepts underlying western thought and philosophy. They are not the result of experimentation, but of the application of the historical methods of the Earth scientist.

The Crustal Evolution Education Project of the National Association of Geology Teachers developed over 32 activities on plate tectonics (available from Wards Science Establishment, Inc.). Many exemplify the historical and descriptive approaches of the Earth scientist, and we as science teachers can use them to acquaint our students with the thought processes behind such methods. They include, for example, activities on Iceland (where students plot data on rock ages), paleomagnetism, and earthquakes. Working as teams, students analyze the data, and, based on their interpretations, determine the location of the mid-Atlantic Ridge as it crosses Iceland.

Other activities use data from deep sea cores to verify the spread of the Mid-Atlantic ocean basin, or paleomagnetic data to determine the relative positions of India as it moved up to impact the Asian continent.

THE CONCEPTUAL CONTRIBUTIONS

We are now able to look at the Earth in a dramatically different way. Instead of being forced to examine small areas of terrain or local atmospheric changes, scientists can now view the planet holistically. This has been made possible because of many advances in technology. Sophisticated satellites can observe biological, chemical, geological, and physical changes over enormous areas. Supercomputers now permit the reduction and analysis of huge amounts of data. Communication networks link scientists from many different places on the Earth to work simultaneously on the same projects.

Partly as a result of applying these new tools to the study of our planet,

FIGURE 2. The seven understandings from the Framework for Earth Systems Education (courtesy of The Ohio State University).

- Earth is unique, a planet of rare beauty and great value.
- Human activities, collective and individual, conscious or inadvertent, are seriously impacting planet Earth.
- The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
- The Earth system is comprised of the interacting subsystems of water, land, ice, air, and life.
- Planet Earth is more than four billion years old and its subsystems are continually evolving.
- Earth is a small subsystem of a solar system within the vast and ancient Universe.
- There are many people with careers that involve study of Earth's origin, processes, and evolution.

NOTE

The complete Earth Systems Framework (abstracted in Figure 2) and information about the Program for Leadership in Earth Systems Education is available from the author.

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Earth scientists now speak of the Earth as a system. Rather than having to restrict their study to processes that can be observed in one place at one time, or a few places at several times, they can now look at processes occurring on a global scale and in a time frame stretching back tens of millions of years. Thus we are beginning to receive the first glimmer of understanding of how the Earth system works and how each of its subsystems, such as lithosphere, atmosphere, and hydrosphere interact with each other to produce global changes. It has also been evident that humans and their activities have been a very important agent in changes that have occurred in the past, and will occur in the future. This is now a different planet that we are living on; a complete revolution in our knowledge of our home has occurred. Unfortunately, however, little of this new knowledge has found its way into the curriculum.

Global changes can be thought of as occurring on two different timescales. One is on the order of thousands to millions of years, and includes processes such as plate tectonics, the gradual evolution of mountains, ocean basins, and other large features of the Earth's crust. The other changes occur on the order of decades to centuries, and include processes in subsystems such as the biosphere and atmosphere. It is the latter that is most influenced by our activity—global warming, for example—and therefore of most immediate concern.

To teach these Earth concepts, instructors should use the results of the new technology epitomized by current satellite imagery. In 1977, NASA published *Mission to Earth: Landsat Views the World,* which includes a wealth of high altitude imagery. In 1978, NASA followed with an educators guide that contains ideas on how to use the images. More recent imagery available from NASA allows students to study upwellings and the consequent bloom of phytoplankton, variations in the level of the sea, and the direction of wind at the sea surface on the scale of continents and ocean basins (Figure 1).

A national project is now underway to implement many of the understandings discussed above into the K–12 science curriculum. The Program for Leadership in Earth Systems Education (PLESE), recently funded by the National Science Foundation, is preparing K–12 teacher teams to implement Earth Systems syllabi in their own classrooms and to conduct workshops in their states and locales.

The planning committee of the project, using the results of a 1988 conference of geoscientists and educators held in Washington, D.C., and an analysis of Project 2061 Earth science concepts, developed a framework of seven understandings (Figure 2). PLESE teams organized at summer workshops at the Ohio State University or the University of Northern Colorado used the framework as a guide in developing Earth systems syllabi and in selecting materials to implement the syllabi. Through programs such as this, curricula is developed that will provide our students with a much richer understanding of the nature of science, and more importantly, the nature of the planet on which they live. With such understandings, we as a society will be better prepared to meet a future in which all is changing; our world's economics, politics, and environment.

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Down to Earth Biology

A Planetary Perspective for the Biology Curriculum

Rosanne W. Fortner

INCREASED attention to the biosphere's relationship to the other Earth subsystems—hydrosphere, lithosphere, atmosphere—could help enhance student understanding in biology. Recent international comparison studies do not speak well for levels of biology achievement in the United States. Our 13 year olds ranked ninth out of 12 countries/provinces in the life sciences. Even our advanced students in second-year biology place at the bottom of a list of 14 countries (Jacobson & Doran 1988). The literature of science education is a further reminder that all is not well within the biology curriculum. Studies of naive conceptions demonstrate a lack of basic understanding of concepts such as nutrient cycling, natural selection (Greene 1990) and the water cycle (Bar 1989). A number of these difficulties rest at the interface of biology and Earth sciences.

Bringing biology "down to Earth" might also be the key to making sound decisions on matters of national policy and international assistance. Deforestation, for example, is an atmospheric issue, not just a biological one; ozone depletion creates human health problems; abuses of the ocean are manifested in human habitats and marine mammal welfare; and an understanding of organic evolution rests on a fundamental awareness of "deep time," describing the great age of Earth as revealed through its geologic structure.

The Earth system can become the conceptual base of the science curriculum and play a major role in the restructuring efforts now underway through the American Association for the Advancement of Science's Project 2061 and the National Science Teachers Association's Scope, Sequence and Coordination. When our leaders need to apply the results of biological research in making decisions, the earth sciences can offer a unique perspective and body of knowledge.

According to Vic Mayer, leading advocate of a modern movement in earth systems education (Mayer 1991a), contributions of earth science to the K-12 curriculum take at least three forms:

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- Philosophical—how we think about the position and role of humans in the universe
- Methodological—how we investigate our surroundings
- Conceptual—what we know about our world and how it functions.

The purpose of this article is to explore examples of how the biology curriculum could build upon these contributions to achieve greater relevance for students and greater value as a basis for decision making.

Philosophical Contributions

One of the major obstacles to acceptance of evolution as a valid scientific concept is a lack of understanding of the age of the Earth. Before James Hutton wrote *Theory of the Earth* in 1795, the planet was assumed to be only about 6000 years old. It was Hutton who introduced the concept of deep time. Earth processes like those in action today have been going on throughout the history of the planet, and this concept of "the present is the key to the past" (Lyell 1830–1833) forms the basis for all our studies of the Earth. Charles Darwin accepted this idea and applied it in developing his theory of organic evolution.

In accepting the Earth as being of great age one can reject the idea that the world was created specifically for human use. We now understand the planet evolved over billions of years, and the human species is a very recent result of a biological evolution. Because some species have become extinct along the way, there is reason enough to believe that we may not be the ultimate and culminating product of the evolutionary process!

The place of deep time in the science curriculum is clear, but the methods for getting it there are not simple. Frequently the concept is taught by analogy. For example, Mark Twain likened the Earth's history to the height of the Eiffel Tower, with human history represented by the skin of paint on the top of the highest pinnacle-knob. Teachers often put great creative effort into teaching about the great expanse of time. One teacher has the students in all his classes count dots printed on sheets of paper. When a page is finished, it is taped to the wall. By the day's end all

the walls are full, and only 1 million have been counted.

Methodological Contributions

For decades the science curriculum has been teaching people the scientific method—*the* scientific method, translated as how to conduct a proper experiment. Indeed, we can trace many of the major achievements and bodies of knowledge in biology to experiments: Mendelian genetics, the germ theory of disease, biological clocks, recombinant DNA and the like. Of course, there are many instances when experimentation is the preferred means of data acquisition. An observation leads to a hypothesis, data are collected by manipulating some variables while others are held constant, data are analyzed and the hypothesis is accepted or rejected. If Joseph Lister had not experimented to control variables, physicians might still be doing excellent surgery but watching patients die as they did before experiments in aseptic medical procedures. We could be growing mice by Needham's recipe—putting old rags and corn in a barn, whereupon mice arise!

It is a disservice to students, however, to convince them by rote or by example that there is only one method of doing science. Science is characterized by the gathering and analysis of real world data to learn how the world operates. Darwin didn't arrive at his theory of organic evolution by experimentation but by analysis of descriptive data. We would never intentionally experiment to find out what would happen to a population of wild birds if the birds' entire habitat were destroyed; instead we study examples of how habitat loss has affected other bird species and compare those with the circumstances of the species in question.

Data are frequently available to study phenomena we can't control in space or time. "Hands-on" science can be done with such historical and descriptive data from existing sources. For example, one can chart changes in stream macroinvertebrate populations over time or study tombstones to compare the life spans of people at different times in the past.

Historical data continue to make their way into modern science news because studies of the accumulating records of the Earth, both the living and the nonliving parts, assist us in charting trends and making predictions about the future. That living things influence and are influenced by their environment is a basic concept in biology. The "wood cookies" (tree cross-sections) common in life science classrooms are used to find the age of trees and make inferences about their environments. Modern interpretation of tree rings correlates ring width with climate conditions and helps scientists identify recurrent patterns of weather. Other organisms reflect characteristics of their environment in their growth rings as well: tortoises' shell sections, fish scales and otoliths, bands of chemical deposits in reef building corals. Global weather signals may emerge when several biological sources of historic climate data are compared. What we use are data sets of Earth's history, reaching back into deep time and continuing into the future. And because all these data sets are continuously accruing, predictions about tomorrow can be evaluated through monitoring of the changes occurring now. The biological concepts derived from the study of such data are not the results of experimentation but of historical methods used by the Earth scientist.

The changes identified through historical data may be of a time scale of thousands to millions of years, as in evolution, or a time scale of decades to centuries, as in primary succession, or one of days to years, as in tortoise growth. A National Science Foundation-sponsored project at Ohio State University is developing "Secondary Science Curriculum Modules for Global Change Education," which involves the historical method and various time scales.

By interpreting data from animal and plant growth, students can see how the growing conditions of Earth's climate have changed in the recent past. By comparing more recent biological data with ice cores from world glaciers, students see that the glaciers preserve a longer time scale or deeper time, leading them to consider if a recurring trend may be in progress. Another activity uses a time scale on the order of decades, using the historical catch of striped bass in the North Atlantic to explore reasons for the recent lack of fishing success noted in singer Billy Joel's "Downeaster Alexa."

Conceptual Contributions

Increasing applications of satellite imagery in the media, in textbooks and even as art forms show that a genuine "world view" is within our grasp. We can see the Earth as a system with all its parts interconnected. Sophisticated satellites with a wide array of image processing options can observe Earth's biological, geological, chemical and physical aspects and their changes. We receive the satellite information, process it through the imaging software, untangle the data with supercomputers and then share the data with scientists in many parts of the world almost as quickly as it is received. Our communications and data processing capabilities are staggering. The smoke from forest fires in Rondonia, the dried vegetation of drought-stricken California and the productivity of ocean surface waters are all known to us by degree and extent from space platforms many miles above the surface of the planet.

Partly as a result of this world view, scientists from

Fig 1. The 7 basic understandings in the Framework for Earth Systems Education.*

- Earth is unique, a planet of rare beauty and great value.
- Human activities, collective and individual, conscious and inadvertent, are seriously impacting planet Earth.
- The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.
- The Earth system is comprised of the interacting subsystems of water, land, ice, air and life.
- Planet Earth is more than 4 billion years old, and its subsystems are continually evolving.
- Earth is a small subsystem of a solar system within the vast and ancient universe.
- There are many people with careers that involve study of Earth's origin, processes and evolution.

*Courtesy of Ohio State University. Complete Framework available in Mayer, V.J. (1991b). A Framework for Earth Systems Education. *Science Activities*, 28(1), 8–9.

all disciplines are beginning to treat the Earth as a system. We prepare global climate models, organize Worldwatch expeditions and report threats to biological diversity in terms of worldwide losses. The nations of the world unite to save whales stuck in the ice and to put out fires in flaming oil wells. Perhaps we have begun to see that ours is a collective future. The more we learn about Earth, the more we come to understand how closely its subsystems—the biosphere, hydrosphere, lithosphere, atmosphere and cryosphere—are intertwined in the production of and response to global changes. What affects one subsystem ultimately affects them all. It has also become more apparent from our views of earth that humankind has been an important agent of change in the past, and probably will continue to be in the future. With the historical data showing our impact in the past, and the signs of our more recent effects, we can more accurately project trends of potential changes on Earth that are attributable to human activity.

Getting Down to Earth

To bring these new technologies and the resulting awareness of connections into the classroom, instructors can use the spectacular satellite images available from the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. An excellent set of diverse images from these agencies is available, with interpretation, as "Oceanography from Space" (NASA 1989). Additional information sources are becoming more accessible as well, in the form of compact disc—"read only" memory (CD-ROM) technology. In a Joint Educational Initiative (JEdI), images and databases from the U.S. Geological Survey, NASA and NOAA have been combined on three 700-megabyte CDs to demonstrate the use of such scientific research tools in the classroom (Sproull 1991). Not only can students examine satellite photos of the Yellowstone fires, they can detect the vegetation differences of biomes through the seasons, model coastal flooding to see the extent of wetland loss and compare ozone levels in their local region with those of Antarctica. Other biology CDs, with widely varying prices and degrees of user-friendliness, include bibliographic databases on "Aquatic Sciences and Fisheries," "Wildlife and Fish Worldwide," the "Life Sciences Collection" and the "Natural Resources Metabase," covering more than 45 government databases. CDs with images as data include "Audobon's Birds of America," complete with bird calls; "Mammals: A Multimedia Encyclopedia," including animations and a game; and "Down to Earth" clip art for desktop publishing. (A list of selected CDs and sources is available from the author.)

Many science teachers are aware of the electronic networking that is bringing classrooms together through the National Geographic KidsNet. That concept is growing in popularity as a means of sharing data about local environmental quality. The Backyard Acid Rain Kit (BARK) from Canada and the Global Rivers Environmental Education Network (GREEN) from the University of Michigan are among new attempts to involve students in the active process of data collection, sharing and analysis, under conditions in which the correct answers to problems are unknown. The student's world view is built from within, as it should be, with relevance first to home and then to the rest of the world.

The interrelationships apparent from the world view technologies must enter the science curriculum at all levels. In the restructuring efforts underway at the national level, many of the implementation models are interdisciplinary ones. A strong focus on understanding the Earth can enrich the science curriculum and give it a relevance that will encourage more student interest in science careers.

Teachers who are ready to get "down to Earth" will be assisted by a Framework for Earth Systems Education, developed and validated by scientists, teachers and science educators nationally (Figure 1). The developers feel that the Framework embodies the big understandings that all students should have about the Earth, whether they are learned in biology classes, environmental education, geography or art. An NSF-sponsored Program for Leadership in Earth Systems Education (PLESE) at Ohio State University (Mayer, in press) is enhancing teachers' abilities to use interdisciplinary studies of Earth to enrich their science curricula as well as to provide a more realistic look at how scientists function. Ultimately, the goal is a future in which decision makers champion the Earth in their political and economic choices.

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Earth Appreciation

by Victor J. Mayer

Reflections of earth science in art.

Do you often find it difficult to illustrate a scientific process in a way that will capture the interest of your students? Earth science teachers are fortunate to have help when faced with this problem. They can tap into a variety of sources outside of the science teaching resources that are normally available. They can make the study of earth processes fascinating by appealing to the variety of interests students have in history, art, and literature. Often, just the right information or illustration can be found in one of these fields that can help a certain student or class grasp a certain topic more thoroughly.

A number of years ago, for example, there was a popular movie entitled *Ten Who Dared*. It was an account of the exploration of the Grand Canyon by Major John Wesley Powell during the late 1800s. Powell was a fascinating man and an excellent example of how historical figures can be used to introduce certain areas of earth science.

Powell, an officer during the Civil War, lost his arm during the battle at Shiloh. Despite this handicap, he later became one of our country's most prominent scientists. He founded the Bureau of Ethnology and helped to found the United States Geological Survey. In 1888, he was elected president of the American Association for the Advancement of Science.

Powell was an excellent writer. His exciting account of his travels through the West includes observations of the Grand Canyon and the Colorado River that can be used to teach basic concepts of erosion, sedimentation, stratigraphy, and geologic history. The following is a sample from his journal:

"July 13—Extensive sand plains extend back from the immediate river valley, as far as we can see, on either side. These naked, drifting sands gleam brilliantly in the midday sun of July. The reflected heat from the glaring surface produces a curious motion of the atmosphere; little currents are generated and the whole seems to be trembling and moving about in many directions, or, failing to see that the movement is in the atmosphere, it gives the impression of an unstable land. Plains, and hills, and cliffs, and distant mountains seem vaguely to be floating about in a trembling, wave-rocked sea, and patches of landscape will seem to float away, and be lost,

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Adams's choice of light, shadow, and angle has converted a rock outcrop into an artistic image (left). One gets a feeling of motion reminiscent of the manner in which particles forming sandstone were deposited. Using such images to teach geological concepts such as wind deposition provides not only knowledge of the concept but also an esthetic feeling for a portion of the Earth.

and then reappear. (Powell, 1957, p. 49)"

This excerpt is typical of Powell's writing. What is impressive is his ability to put action and excitement into words and also his very vivid descriptions of natural phenomena, such as air currents generated by the heated sand surface. How much more interesting is this writing than that which we normally find in science textbooks.

A fascinating series of events from our history that can be used to illustrate not only the nature of earth processes but also how such processes have been used to mislead people are related by Allan Eckert's book *The Frontiersman* (1967). He tells of the great Indian leader Tecumseh, who if the historical records are correct, was born in a year that a comet visited our solar system. According to Indian legend, this gave him great power.

During the early 1800s, he was attempting to rally the Indian tribes for an attempt to reclaim their lands from the Americans. During his travels to raise support, he told his allies to expect two signs that would confirm his power and signal them to join him in battle. On the night of November 16, 1811, a meteorite flashed across the Midwestern sky. Eckerts' allies took this as the first sign. Then, 30 days later, an even more powerful event occurred. Eckert provides a fascinating description:

"In the south of Canada, in the villages of the Iroquois, Ottawa, Chippewa and Huron, it came as a deep terrifying rumble. Creek banks caved in and huge trees toppled in a continuous crash of snapping branches. In all the Great Lakes, but especially Lake Michigan and Lake Erie, the waters danced and great waves broke erratically on the shores, though there was no wind. In the western plains there was a fierce grinding sound and a shuddering, which jarred the bones and set teeth on edge. Earthen vessels split apart and great herds of bison staggered to their feet and stampeded in abject panic . . . . To the south whole forests fell in incredible tangles. New streams sprang up where none had been before. In the Upper Creek village of Tuckabatchee every dwelling shuddered and shook and then collapsed upon itself and its inhabitants . . . . The Mississippi itself turned and flowed backwards for a time. It swirled and eddied, hissed and gurgled, and at length, when it settled down, the face of the land had changed. New Madrid was destroyed and tens of thousands of acres of land . . . vanished forever; and that which remained was ugly and austere. (pp. 538-540)"

Many of Tecumseh's Indian allies accepted this, the first of a series of shocks comprising the great New Madrid earthquake, as the second sign. They joined Tecumseh, along with their British allies, to challenge the Americans. Tecumseh, however, was killed very early in the battle, proving that he had no special power other than the force of his personality. His Indian allies scattered and the Americans went on to defeat the British and secure the Northwest Territories.

Excellent prose about earth pro-

Detail from the painting "The Voyage of Life, Youth" by Thomas Cole, photo courtesy of the National Gallery of Art

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cesses can also be found in novels and other literature. James Michener, for example, has included very dynamic descriptions in some of his historical novels. In *Hawaii* (1959), he describes the origin of the islands in very vivid prose, providing insight into the volcanic processes that formed and continue to mold the islands.

In *Centennial* (1974), he describes the evolution of the Rocky Mountains over billions of years of time. He devotes a chapter each to the development of the Rocky Mountains, the evolution of the life of the area, and the early presence of humans. Especially interesting is the section on the habitat and life of the dinosaurs that inhabited the region during the Cretaceous period. Their remains are preserved in the famous Morrison formation, which is exposed in a dramatic road cut on the outskirts of Denver.

In his most recent book, *Alaska* (1988), he gives very understandable explanations of how Alaska grew over the past billion years. He accurately describes the processes of plate tectonics that accounted for its formation and the recent ideas of "terranes" that geologists now think accumulated over millions of years to form the Alaskan peninsula. Michener also provides insight into the methods used by geologists to interpret the history of an area, as the following passage shows.

> In one of the far wastes of the South Pacific Ocean a long-vanished island-studded landmass of some magnitude arose, now given the name Wrangellia, and had it stayed put, it might have produced another assembly of islands like the Tahiti group or the Samoan. Instead, for reasons not known, it fragmented, and its halves moved with a part of the Pacific Plate in a northerly direction, with the eastern half ending up along the Snake River in Idaho and the western as a part of the Alaskan peninsula. We can make this statement with certainty because scientists have compared the structure of the two segments in minute detail, and one layer after another of the terrane which landed in Idaho matches perfectly the one which wandered to Alaska. The layers of rock were laid down at the same time, in the same sequence and with the same relative thickness and magnetic orientation. The fit is absolute, and is verified by many matching strata. (p. 5)

Michener's novels, Eckert's historical accounts, and Powell's journals are only a few examples of writing suitable for the science classroom. There are many other writers and poets who, over the years, have provided descriptions that can be substituted for the often dull and stilted writing found in our science texts. It is simply up to teachers to be on the alert for such passages.

The Earth and its processes have been an inspiration to many artists.

Art can also provide illustrations of earth processes. I've been an avid photographer since the 8th grade. Those who share my enthusiasm for the hobby will be familiar with the name Ansel Adams. He was my hero and I have always aspired to photograph landscapes as sensitively and inspirationally as he did.

Adams was born and raised in San Francisco. When he was four, an aftershock of the great earthquake of 1906 knocked him against a brick wall, breaking his nose. His face bore the mark of that earthquake throughout his life. He went on to become an ardent conservationist and one of our most famous photographers. His interpretations of western landscapes is art of the highest merit. But they also illustrate earth proces_es and can serve as excellent teaching tools. (See photograph on pages 60-61.)

The Earth and its processes have been an inspiration to many artists. One of my favorite art selections is a series of four paintings completed during 1839 and 1840 by the American painter Thomas Cole. Entitled *The Voyage of Life*, they depict the moods of the various stages in the human life cycle. In the detail from "Youth," found on page 62, the verdant shore provides a setting of excitement and energy as the youth looks to a future of promise and productivity. The other paintings depict childhood, maturity, and old age. In each, Cole has used planet Earth and its processes to express his feelings about life and the stages that we all move through.

An inspired teacher will help students experience the planet the way Cole did, to see in Earth processes a reflection of the intimate relationship between humans and their environment, and help them reach an understanding of our dependence upon a rich and fruitful environment and our need to sustain its quality for our own benefit and that of future generations.

Our beautiful Earth

As science teachers, we can appeal to the right brain, as well as the left brain, of our students in our attempts to get them involved in science. They should encounter planet Earth through our courses as a thing of beauty; its processes developing spectacular vistas as they operate over eons of time. They should be able to marvel at the beauty of an ice crystal sparkling in the sun as a glacier melts. They must come to value the Earth, not just for the minerals it gives up to industry, or the oil it provides for our cars, but for the sunsets from its atmosphere and the symmetry in a crystal. As teachers help their students achieve a rational understanding of the Earth and its processes through a study of science, they also can provide a firm foundation for the development of a system of values that honors the enduring spirit of humankind and that recognizes its dependence upon the esthetic qualities of planet Earth. ■

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ERIC CSMEE Digest

Clearinghouse for Science, Mathematics, and Environmental Education EDO-SE-93-2 March 1993

Earth Systems Education

Victor J. Mayer

National concerns about the quality and effectiveness of science teaching have resulted in several major efforts directed at restructuring the nation's curriculum, including Project 2061 of the American Association for the Advancement of Science (AAAS, 1989) and the Scope, Sequence, and Coordination project of the National Science Teachers Association (NSTA, 1992). A third effort is the Earth Systems Education program centered at The Ohio State University and the University of Northern Colorado (Mayer, editor, 1992). Its philosophy and approach to science content is consistent with the better-known projects but differs in significant respects, especially in its focus on planet Earth.

Understanding Planet Earth

Over the past two decades there have been tremendous advances in the understanding of planet Earth in part through the use of satellites in data gathering and super computers for data processing. As a result, Earth scientists are reinterpreting the relationships among the various science sub-disciplines and their mode of inquiry. These changes are documented in the "Bretherton Report," developed by a committee of scientists representing various government agencies with Earth science research mandates (Earth Systems Science Committee, 1986). These advances also prompted the organization of a conference of geoscientists and educators in April, 1988, to consider their implications for science curriculum renewal. The 40 scientists and educators, including many scientists from the agencies responsible for the Bretherton Report, developed a preliminary framework of four goals and ten concepts about planet Earth that they felt every citizen should understand (Mayer and Armstrong, 1991). Through subsequent discussions with teachers and Earth science educators at regional and national meetings of the NSTA, a renewed concern emerged for a more adequate treatment of planet Earth in the nation's science curriculum.

Infusion through Teacher Enhancement

In Spring of 1990, the Teacher Enhancement Program of the National Science Foundation awarded a grant to The Ohio State University for the preparation of leadership teams in Earth Systems Education—PLESE, the Program for Leadership in Earth Systems Education. The program was designed to infuse more content regarding the modern understanding of planet Earth into the nation's K–12 science curricula.

In preparation for PLESE, a planning committee composed of ten teachers, curriculum specialists, and geoscientists met in Columbus, Ohio in May, 1990, to develop a conceptual framework to guide the program. Preliminary work included the analysis of the Project 2061 report for content related to Earth systems. The committee used this analysis combined with the results of the 1988 conference to develop a framework consisting of seven understandings. This Framework for Earth Systems Education provided a basis for the PLESE teams to construct resource guides and to select teaching materials for use in infusing Earth systems concepts into the science curriculum in their areas (Mayer, 1991). The program has worked with over 180 teachers in three member teams including an upper elementary teacher, a middle school teacher, and a high school teacher during three-week long summer programs. These teams have conducted Earth Systems awareness workshops in their states, communities, and at national NSTA conferences. During the summer of 1993, selected participants prepared resource guides for use at each of the three grade levels.

Earth Systems Education Framework

The PLESE Planning Committee intentionally arranged the understandings of the Earth Systems Education Framework into a sequence (Mayer, 1991). The first emphasizes the aesthetic values of planet Earth as interpreted in art, music, and literature. By focusing on students' feelings towards the Earth systems, the way in which they and others experience and interpret them, students are drawn into a systematic study of their planet. An aesthetic appreciation of the planet leads the student naturally into a concern for the proper stewardship of its resources: the second understanding of the framework (Mayer, 1990). A developing concern for conserving the economic and aesthetic resources of our planet leads naturally into a desire to understand how the various subsystems function and how we study those subsystems: the substance of the next four understandings. In learning how the subsystems function, students must master basic physics, chemistry, and biology concepts. The last understanding deals with careers and vocations in science, bringing the focus once again back to the immediate concerns and interests of the student (Fortner, editor, 1991).

Earth Systems Education and Science Curriculum Restructuring

Teachers using the Framework to develop their resource guides saw its application for the development of integrated science curricula, an objective of both Project 2061 and NSTA's SS&C effort. What could be more natural than developing K–12 science curricula using the subject of all science investigations—planet Earth—as the unifying theme? Any physical, chemical, or biological process that citizens must understand to be scientifically literate can be taught in the context of its Earth subsystem. That is the thought that has guided a number of teachers and curriculum specialists in considering the implications of Earth Systems Education for the nation's science curriculum reform efforts (Mayer, et al, 1992).

The Earth Systems Education effort also seeks to implement a more holistic philosophy of the nature of science into what has been criticized as a reductionist curriculum. Stephen Gould, occupant of the Agassi Chair of Paleontology at Harvard University has characterized the nature of science as it is

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presented in today's schools in the United States:

> Most children first meet science in their formal education by learning about a powerful mode of reasoning called "*the* scientific method." Beyond a few platitudes about objectivity and willingness to change one's mind, students learn a restricted stereotype about observation, simplification to tease apart controlling variables, crucial experiment, and prediction with repetition as a test. These classic "billiard ball" modes of simple physical systems grant no uniqueness to time and object—indeed, they remove any special character as a confusing variable—lest repeatability under common conditions be compromised. Thus, when students later confront history, where complex events occur but once in detailed glory, they can only conclude that such a subject must be less than science. And when they approach taxonomic diversity, or phylogentic history, or biogeography—where experiment and repetition have limited application to systems in total—they can only conclude that something beneath science, something merely "descriptive," lies before them (Gould, 1986).

The commonly held image of science that is reinforced in our classrooms is that of controlled laboratory experiments conducted by a balding man wearing a white lab coat. Basic to the Earth Systems Education approach is to give a more comprehensive understanding of the nature of science and its intellectual processes including the historical descriptive approaches commonly used by the earth and biological sciences (Mayer, et al, 1992).

Earth Systems Education efforts also take a constructivist approach to learning both in workshops conducted by the staff and in the curriculum restructuring efforts. Most learning goes on in small collaborative groups working on real issues and problems dealing with the Earth System. Another basic tenant is that curriculum restructuring must be a "grass-roots" effort. Teachers are the curriculum developers. Other individuals, be they university professors, professional association staff, state or local level administrators, serve a facilitating function. The curriculum itself must be developed and therefore owned by the teachers who teach it (Mayer, et al, 1992).

Earth Systems Education Projects

Several projects are underway to test aspects of Earth Systems Education. The oldest and furthest along is the implementation of an integrated Biological and Earth Systems (BESS) science sequence into the high schools in the Worthington (OH) School District (Fortner, et al, 1992). It is a required sequence replacing both Earth science at the 9th grade and Biology at 10th. The sequence is organized around basic Earth systems issues such as resource supply, global climate change, and deforestation. The program incorporates collaborative learning and problem-solving techniques as major instructional strategies. Current technology is also used including on-line and CD-ROM databases for accessing current scientific data for use in course laboratory instruction. Ten additional Ohio and New York school systems are now studying the BESS program for its implications for their curriculum restructuring efforts.

Other efforts at elementary, middle, and high school levels are now underway in school districts in New York, Colorado, Ohio, Oregon, and Illinois.

Conclusion

The time appears to be ripe for the first total restructuring of the science curriculum since the current high school course sequence was established in the late 1800s. The dramatic changes that have taken place in science, in the understanding of how science is learned, in the evolving demands of technology, and in the pressures they place on our environment require this restructuring. Earth Systems Education offers an effective strategy. As a first step, it infuses planet Earth concepts into all levels of the K–12 science curriculum. In the long run, it provides an organizing theme for a K–12 integrated science curriculum that could effectively serve the objectives of scientific literacy and at the same time provides a basis for the recruitment of talent into science and technology careers.

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OERI This digest was funded by the Office of Educational Research and Improvement, U.S. Department of Education under contract no. RI-88062006. Opinions expressed in this digest do not necessarily reflect the positions or policies of OERI or the Department of Education.

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FRAMEWORK FOR EARTH SYSTEMS EDUCATION

Understanding #1: *Earth is unique, a planet of rare beauty, and great value.*
- The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts.
- Human appreciation of Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

Understanding #2: *Human activities, collective and individual, conscious and inadvertent, affect Earth Systems.*
- Earth is vulnerable and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts of industrialization pollute the air, land and water and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

Understanding #3: *The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.*
- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools and modern technology are used to create, test, and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

Understanding #4: *The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.*
- The subsystems are continuously changing through natural processes and cycles.
- Forces, motions and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth system has characteristic properties, structure and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- Weathering, erosion and deposition continuously reshape the surface of Earth.
- The presence of life affects the characteristics of other systems.

Understanding #5: *Earth is more than 4 billion years old and its subsystems are continually evolving.*
- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

Understanding # 6: *Earth is a small subsystem of a Solar system within the vast and ancient universe.*
- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe.
- Nine planets, including Earth, revolve around the Sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

Understanding #7: *There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.*
- Teachers, scientists and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University and the University of Northern Colorado.

For further information on Earth Systems Education contact the Earth Systems Education Program Office, School of Natural Resources, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210.

2

The National Context for Science Education Reform

As science teachers, you are familiar with the many projects at the national and state levels that are attempting to improve science curriculum and instruction. You can use this national concern to help convince parents and administrators to invest the time and money for your efforts at change. In this section we provide a condensed and focused summary of the major influences on science reform that are accommodated in Earth Systems Education.

Project Synthesis

Three national studies of science teaching and curriculum supported by the National Science Foundation and conducted in the late 1970s documented the rising concerns within the science education community about the nature of our science curriculum and teaching. The problems with science education revealed by these three studies were summarized in *Project Synthesis* (Harms and Yager, 1981). This report made four general recommendations about needed changes in K–12 science curriculum. These recommendations are contained under four Goal Clusters:

Goal Cluster I—Personal Needs: Science education programs should prepare individuals to use science for improving their own lives and coping with an increasingly technological world.

Recommended topics under this Goal Cluster are energy, population, human engineering, environmental quality, use of natural resources, space research and national defense, sociology of science, and effects of technological developments.

Goal Cluster II—Societal Needs: Science education programs of the community should prepare its citizens to use science to deal responsibly with science–related societal issues.

The same topics as in Goal Cluster I were recommended to fulfill the goals in this Cluster. Future citizens should be prepared to understand the relationship between the use of energy, for example, and its impact on society.

Goal Cluster III—Academic Knowledge of Science: Science education programs should insure the continued development and application of scientific knowledge by maintaining a "critical mass" of fundamental scientific understanding in the American public.

Attention must be paid to the development of an adequate background in science relating especially to the content goals in Clusters I and II. The future citizen must be prepared to understand the tentative nature of scientific knowledge. Programs must provide an opportunity for the citizen to gain current knowledge in science.

Goal Cluster IV—Career Awareness and Education: Science education programs of the community should insure the continued development and application of scientific knowledge by maintaining a continual supply of citizens with scientific expertise.

This goal can be achieved through developing an appreciation for career opportunities in science, helping the student make career decisions, and by providing a broader and more holistic view of science and technology.

Project Synthesis provided recommendations for future curricular change, based on what were perceived as the needs of society in the late 70s. It spawned the Science, Technology, and Society (STS) movement led by educators such as Robert Yager from the University of Iowa and Rustum Roy of Penn State University. A number of school systems around the country have modified their science curricula to accommodate the major features of STS, basically to demonstrate the applications of science in technology and society.

> *As national priorities change, so too must our understanding of what constitutes the essential knowledge of science that is to be conveyed to every future citizen. Earth Systems Education does this. As such it is unique among the recent reform efforts, most of which were spawned during the cold war.*

Science for the Future

Project Synthesis and STS provided a foundation for later projects, such as Project 2061 discussed below. Note, however, that one of the major topics cited under Goal Cluster I was "national defense." This was important when *Project Synthesis* was developed, because of our competition with the Soviet Union. This competition no longer exists. National defense, in the context of the 70s, is no longer a national priority. The insistence that we form a new definition of science comes from Rep. George E. Brown Jr., former Chair of the House Committee on Science, Space, and Technology. This committee has oversight of most civilian science and technology programs. Brown, in a newspaper article published in several papers in 1992, (quoted from AAAS, 1993b, pp. 111-112) said, "Today there are more human beings living in abject poverty throughout the world than ever before. At home, our global leadership in science and technology has not translated into leadership in infant health, life expectancy, rates of literacy, equality of opportunity, productivity of our workers, or efficiency of resource consumption. Neither has it overcome failing education systems, decaying cities, environmental degradation, unaffordable health care, and the largest national debt in history."

"Must science and technology continue to feed the historical cycle of more consumption, more waste, more economic disparity? Or can our research lead us out of that cycle, and create a new trajectory for cultural evolution?" Science curriculum developers need to consider Brown's concerns about the ability of our current science and technology programs, founded in the World Wars and Cold War, to assist in solving our current problems. They must ask themselves: what does this new view of the role of science in our society say about the content of a science curriculum for educating citizens as to the proper role and methodology of science in this post-war world? In this context even projects as recent as Project 2061 and NSTA's Scope, Sequence, and Coordination are outdated.

Project 2061

In 1987, the American Association for the Advancement of Science sponsored a program to fundamentally change science as taught in American schools. Five panels of scientists met over a two-year period to define the content and character of "*Science for All Americans*." This became the title of the report of Project 2061 (AAAS, 1989). Much of the science content recommended was already found in school curricula. It differed, however, in two fundamental ways. First, the traditional boundaries between the disciplines of Earth science, biology, physics, chemistry, and mathematics are softened and the connections emphasized. Second, "the amount of detail that students are expected to retain is considerably less than in traditional science ... courses. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures." The following recommendations are especially pertinent to teachers developing Earth Systems Education programs:

> To ensure the scientific literacy of all students, curricula must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid subject-matter boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that strongly influences—and is influenced by—human thought and action; and to foster scientific ways of thinking.
>
> The effective teaching of science ... must be based on learning principles that derive from systematic research and from well-tested craft experience. Moreover, teaching related to scientific literacy needs to be consistent with the spirit and character of scientific inquiry and with scientific values. This suggests such approaches as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of

evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity.

In Chapter 13, *Effective Learning and Teaching*, of the Project 2061 report the following recommendations are made:

Teaching Should Be Consistent With the Nature of Scientific Inquiry

Start with questions about nature
Engage students actively
Concentrate on the collection and use of evidence
Provide historical perspectives
Insist on clear expression
Use a team approach
Do not separate knowing from finding out
De-emphasize the memorization of technical vocabulary

Science Teaching Should Reflect Scientific Values

Welcome curiosity
Reward creativity
Encourage a spirit of healthy questioning
Avoid dogmatism
Promote aesthetic responses

Science Teaching Should Aim to Counteract Learning Anxieties

Build on success
Provide abundant experience in using tools
Support the roles of girls and minorities in science
Emphasize group learning

Science Teaching Should Extend Beyond the School

Teaching Should Take Its Time

Project 2061 has published a document entitled *Benchmarks for Science Literacy* (AAAS, 1993a) intended to provide guidance to the science curriculum developer. It delineates the content that its authors believes should be known by a student at each of four levels, at the end of second, fifth, eighth, and twelfth grades.

The benchmarks are organized in the same manner as the content of *Science for All Americans*. Examining the Benchmarks book, its vast list of topics might cause one to wonder if its implementation would indeed foster the objective of reducing the amount of detail taught in current science curricula.

> *The Benchmarks can provide assistance to the science teacher attempting to develop an Earth Systems curriculum. To use them a teacher needs to use the seven Earth Systems Understandings as a "screen" through which the current relevance of each of the benchmarks can be evaluated. Those that pass the screen can help to provide a foundation for an integrated ESE curriculum.*

SCOPE, SEQUENCE, & COORDINATION

Another major national project is the Scope, Sequence, and Coordination Project of the National Science Teachers Association. Six school systems are involved in revising their secondary science programs through this project. Its major focus is to coordinate the teaching of each of the four sciences, biology, chemistry, Earth science, and physics at each of the grade levels, seventh through twelfth. SS&C has adopted most of the goals of Project 2061. The chart found at the end of this section provides a comparison of the two projects.

NATIONAL STANDARDS

The National Academy of Science through its research arm, the National Research Council, is completing a study leading to recommendations for national standards for science. The standards have been developed (National Research Council, 1994) in five areas: content, teaching, assessment, program, and system. The development of standards in these areas is guided by the following principles:

> All students must have the opportunity to learn the science defined in content standards.

With appropriate opportunities and experiences, all students can learn this science.

Students should learn science in ways that reflect the inquiry used by scientists to understand the natural world.

Learning is an active process that occurs best when each student acts as a member of a learning community.

The quantity of factual knowledge and routine skill must be limited to what is essential or fundamental so that students have the time to attain deep understanding and the thinking power defined in the content standards.

Content, teaching, and assessment standards guide the central features of an education program. The application of these standards and their interactions in a specific place and time provides students with the opportunity to learn what is defined in the content standards.

The content standards have been developed in the following areas; science as inquiry, physical science, life science, Earth and space science, science and technology, science in personal and social perspectives, history and nature of science, and unifying concepts and processes. The Earth and space science standards, for example, are very supportive of an Earth Systems approach (see table below). They can form the core, around which the other content standards can be integrated.

Levels K-4 Properties of Earth materials Objects in the sky
Levels 5-8 Structure of the Earth system Earth's history Earth in the solar system
Levels 9-12 Energy in the Earth system Geochemical cycles The origin and evolution of the Earth system The origin and evolution of the universe

Another example of the concurrence of the Earth Systems Education approach to curriculum content are the "science in personal and social perspectives standards." They support Understandings two, three, and seven (see the following table).

Levels K-4 Personal health characteristics and changes in populations Types of resources Changes in environments Science and technology in local challenges
Levels 5-8 Personal health Populations, resources, and environments Natural hazards Risks and benefits Science and technology in society
Levels 9-12 Personal and community health Population growth Natural resources Environmental quality Natural and human-induced hazards Science and technology in local, national, and global challenges

There are five areas of teaching standards designed to define how science is presented in the classroom. An example is:

> Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning.

There are several areas also being defined in the assessment standards. The following standard entitled "coordination with intended purposes" is an example:

> Assessments are consistent with the decisions they are designed to inform.
>
> Assessments are deliberately designed.
>
> Assessments have explicitly stated purposes.

The relationship between the decisions and the data should be clear.

Assessment procedures are internally consistent.

A subcategory of another of the standards states that "assessments are authentic." In these the standards seem to be suggesting that teachers change their assessment procedures to employ a much broader range of ways to collect data on their students accomplishments. This is consistent with the Earth Systems Education emphasis on the use of authentic assessment procedures.

> *The assessment standards support the use of the types of authentic assessment techniques implicit in the ESE model, including portfolios, rubrics and performance testing.*

The standards also speak to the overall school program; that science should be coordinated with mathematics; that students and teachers have access to the necessary time, space, materials, and personnel; and that:

Schools are communities that encourage, support, and sustain teachers as they implement an effective science program.

Schools explicity support reform efforts in an atmosphere of openness and trust that encourages collegiality.

Regular time is provided, and teachers encouraged to discuss, reflect, and conduct research around science education reform.

Teachers are supported in creating and being members of networks of reform.

An effective leadership structure that includes teachers is in place.

> *One of the beliefs implicit in Earth Systems Education is that any true education reform effort comes from the teachers. It is they who must assume the leadership in change.*

The system standards will also speak to issues such as: resource allocation must be consistent with program standards and principles of equity; and coherent and consistent communication must occur among and between system levels aligned with content, teaching, and assessment standards.

Dr. Henry Heikkinen, former Chair of the Curriculum Panel of the National Research Council's Standards Committee, in a presentation to the participants of the final PLESE workshop held in Greeley, CO, in July 1993, summarized the importance and thrust of the national standards effort. He pointed out that it is an attempt to operationally define science literacy. This is a result of industry's desire to have workers at all levels who can:

- Identify problems
- Evaluate alternatives
- Formulate decisions logically
- Separate fact from fiction
- Adjust to unanticipated situations
- Understand written material
- Verify information
- Evaluate worth/objectivity of sources
- Determine what's needed to accomplish assignments

These are but the well worn processes of science under different labels. The science program therefore should be an essential contributor to these workplace skills. He provided the following chart:

Scientist's Science	School Science	Real World
Principles Theories Concepts Facts <->	Experiences Activities Learning Materials Teachers <->	Issues Problems Decision-making Students

Too much school science results from the interaction of the elements on the left side of this chart. The teacher is responsible for interpreting the knowledge from the scientists for implementation in the school. School science, however, must also be affected by the Real World as seen by students. We, therefore, must never forget to look to the right on this chart and create school science programs that can assist students in coping with their Real World exigencies.

The Secretary's Commission on Achieving Necessary Skills

One other report has relevance to science teachers in their attempts to reform science teaching within their schools. The Secretary's Commission on Achieving Necessary Skills (SCANS) was appointed by the Secretary of the Department of Labor to "determine the skills that our young people need to succeed in the world of work." Its report (SCANS, 1992) lists five workplace competencies, including the following:

Resources—Workers "will know how to allocate time, money, materials, space, and staff."

Interpersonal Skills—Workers "can work in teams, teach others, serve customers, lead, negotiate, and work well with people from culturally diverse backgrounds."

Information—Workers "can acquire and evaluate data, organize and maintain files, interpret and communicate, and use computers to process information."

Systems—Workers "understand social, organization, and technological systems; they can monitor and correct performance; and they can design or improve systems."

The report also listed three areas of foundation skills required by the worker. They include:

Basic Skills—reading, writing, arithmetic and mathematics, speaking, and listening.

Thinking Skills—the ability to learn, to reason, to think creatively, to make decisions, and to solve problems.

Personal Qualities—individual responsibility, self-esteem and self-management, sociability, and integrity.

These needs must be addressed in any reformed science program using the Earth Systems approach. They can be developed by greater reliance of teachers on cooperative and collaborative learning techniques and a shift away from the typical competitive atmosphere so prevalent in science classrooms today: fundamental aspects of ESE. ESE philosophy has been designed to guide the development of programs that foster these personal capabilities all students must acquire whether they will be working in a fast food restaurant or in a science research institute in a university or industry.

Summary

Each of the documents cited above provides support for efforts at restructuring science curriculum and teaching following the Earth Systems model. We believe that our model incorporates most of the national recommendations that are based on solid research and practice. It differs, however, in that it modernizes the content of the science curriculum. *Project Synthesis* and Project 2061 are both founded in the era of the cold war, when national defense was our major priority in the development of science in this country. With the cold war now over the content of the science curriculum must change to accommodate the changing national priorities for science. National political leaders are saying that we must now focus on the environmental and social problems that have been left in the wake of the cold war. Science, to survive as an important national resource, must change itself accordingly. Earth Systems accommodates this changing perspective on science literacy. It provides a focus for the science curriculum which otherwise does not exist. That focus is Planet Earth, its appreciation and stewardship.

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Eastern Center PLESE participants at Ohio State testing cooperation and interdependence.

What IS the Difference Between Project 2061 and SS&C?

Obvious similarities between Project 2061 of the American Association for the Advancement of Science (AAAS) and Scope, Sequence, and Coordination (SS&C) of the National Science Teachers Association (NSTA) prompt such a question. In part, the resemblance is deliberate: NSTA endorses the goals in Project 2061's *Science for All Americans* and incorporated them into its core curriculum and defining documents, *Vol. I: The Content Core*, and *Vol. II: Relevant Research*.

NSTA's SS&C
A major reform of science at the secondary level that advocates carefully sequenced, well-coordinated instruction in all the sciences that all students study every year for seven years so that students acquire a greater depth of understanding in science.

PROJECT 2061
A long-term reform initiative to transform K-12 education for the 21st century through a coordinated set of reform tools for school districts to use in developing their own curricula so that all students achieve science literacy.

As the following abridged list suggests, the similarities are substantial.

Project 2061 and SS&C support common reform elements in that they both:

- are broad-based, multi-year initiatives to reform science education;
- emphasize how students actually learn and sequence instruction accordingly;
- advocate science literacy for all students and promote the success of minorities, females, and groups, like the disabled, alienated by traditional science education;
- do not perpetuate the idea that only intellectually elite students are capable of learning and enjoying science;
- question the structure and content of traditional science courses and propose carefully considered alternatives;
- subscribe to the notion that depth of understanding is more critical than broad, superficial coverage of science topics;
- invite variations on curriculum design that retain definitive principles of the project;
- have six sites around the country—through each defines a site differently—developing alternative approaches to teaching and learning;
- involve teachers in the design of curricula and show concern for the professional development of teachers;
- involve university programs, scientific societies, and education associations;
- involve parents, school administrators, science supervisors, and consultants;
- receive funding from the National Science Foundation; and
- emphasize life-long learning.

HOWEVER, the two projects are by no means identical. The following summary highlights some fundamental ways in which the two projects are distinct.

Jim Immelt, BESS teacher, discusses program with Dr. Evgeny Nesterov, State Pedagogical University, St. Petersburg, Russia, and Dr. Suck-wan Choi, Kongju National University, Korea.

NSTA's SS&C	AAA'S PROJECT 2061
> Was launched in 1989.	> Was launched in 1985.
> Addresses curriculum reform in science education.	> Addresses systemic reform in K–12 education for science literacy.
> Defines an SS&C project in terms of the developmental sequencing of abstract and the spacing effect in repetition of topics over several years.	> Defines a Project 2061 effort in terms of the learning goals specified by Science for All Americans (SFAA). Sequencing and spacing are considerations but not definitions.
> Focuses on middle and secondary school science curricula, recognizing that older students bring to the classroom knowledge and notions gained in elementary school.	> Focuses on K–12 curricula with specific benchmarks for science literacy at grades 2, 5, 8, and 12 that analyze and sequence SFAA's learning goals and their interconnections.
> Includes all the natural sciences with their applications to technology.	> Includes all natural and social sciences, mathematics, and technology.
> Recognizes the interdependence of the science disciplines and integrates them in the middle school years, and coordinates them (teaches them as sepearte but related subjects) at the secondary school level.	> Recognizes the interdependence of the sciences and integrates or makes curriculum connections among the science disciplines and with other disciplines, such as the arts and humanities.
> Is relatively short term— a preliminary restructuring designed to induce a long–term change process.	> Proposes long–term reform of the entire K–12 system through blueprints on teacher education, assessment, policy, and other school issues.
> Will restructure curriculum so that students study a science subject area several hours per week every year in grades 6–12 (spacing) or the concepts of science over several years at progressively higher levels of abstraction (sequencing).	> Will provide alternative models for restructuring curriculum: in parallel arrangement, with little overlap among subjects; integrated around issues or phenomenon; or in a mosaic, bound by a variety of organizing principles.
> Identifies instructional materials that can be taught over a seven–year period. These materials will be used by schools wishing to replicate the	> Designs a coordinated set of reform tools— the basic components of curricula with alternative approaches to teaching and learning— for school districts to develop their own curricula.

This chart was developed by Project 2061 (AAAS) and SS&C (NSTA) staff.

3

Successful Strategies For Using Earth Systems Education In Science Curriculum Restructure

In this section we provide you with brief discussions regarding actual restructuring efforts in several schools and school systems that have used the Earth Systems Education model for the development of integrated science curricula. The first describes an effort to integrate the entire K–12 program of a small district in Colorado. The second focuses on the middle school program of a small but rapidly growing district in central Ohio in which there is a single middle school employing five science teachers. The third program is a remarkable, field centered program developed at the Laboratory School of the University of Northern Colorado. It integrates concepts from the sciences with mathematics and social studies, using a single river system, the Cache la Poudre River.

There are also efforts to use the Earth System Science model for restructuring college and university courses to reflect more closely the modern concept of study of planet Earth. Following the article on the BESS program is one that describes a national program for the development of Earth Systems Science courses sponsored by the National Research Council of the National Academy of Sciences. The universities and individuals listed at the end of this article could provide you with support in your efforts at restructuring using the Earth Systems model. The last portion of this section is a report of the restructuring effort at The Ohio State University. These efforts in higher education give even greater credibility to the use of the Earth Systems Education model at the precollege level.

Restructuring K–12 Science in the Fort Lupton, Colorado, Schools

The 1992 Colorado PLESE team consists of one elementary teacher, one middle school teacher, one high school science teacher, and our district science coordinator who functions as our PLESE administrator. Together we developed the following strategy for moving our district's curriculum restructuring effort along the lines of Earth Systems Education:

- Introduce ESE to district superintendent
- Present to local school board
- Guide district science curriculum change with ESE format
- Present follow-up workshops
- Develop support system

Our plan was to gain the support of our district administration by demonstrating how the ESE format correlated with our district learning outcomes.

We approached the superintendent at an informal luncheon meeting in September, following our participation in the summer PLESE workshop at Greeley. We enthusiastically shared with him our recent experience in Earth Systems Education. Sharing our interest in ESE he suggested that we make a 30 minute presentation at the coming School Board meeting. He invited the building administrators to be present so that they might also be informed. Our presentation included the ESE framework, a needs statement, a short video, and opportunities for discussion. Our PLESE administrator and college liaison were there for support and to help answer questions.

After winning support from the school board and building administrators we went on to present at two teacher workshops, each lasting about an hour

and a half. One was presented to teachers of grades 7–12 and the other to grades P–6 (pre-school to six) teachers. These workshops introduced the seven understandings and the spheres. At the elementary level workshop a station was set up for each understanding. Each station exhibited posters, sample activities, hand–outs, and in some cases, a video or slide show. Teachers were free to roam from station to station. The high school level workshop took the format of an open discussion.

Through the workshops we had gained enough support to bring the ESE format to the table at the first district science curricular restructuring committee meeting. Our scope and sequence was based on the four spheres. These were charted on butcher paper around the room to check for gaps. Then each grade level developed objectives based on the seven understandings. Using the new district science curriculum, the fourth grade teachers chose to have each teacher on their team of four teach one sphere. Four high school teachers teamed together to engage in a pilot program called Earth Systems. They were able to enroll twenty students in a two hour time block. The pilot program proved to be successful so the following year Earth Systems was established as a 9th grade class. The following year was spent developing assessments at each grade level. Because it was the year for science curricular restructuring, release time for teacher inservice was already built into the calendar. By approaching the science coordinator and building administrators early it was not difficult to fill those workshop openings with ESE programs.

There have been several workshops offered by the PLESE team throughout the past two years including field trips, demonstrations, infusion activities, university credit, university speakers, and teaming activities. Teachers have been very receptive to ESE because it helps them integrate science in their classrooms. They have made comments such as, "This workshop makes so much sense," or "Now I can see an organization for teaching science that works with other things I'm teaching." Another said, "For the first time I actually enjoy teaching science."

The next step will be to develop a support system consisting of teachers at all grade levels, administrators, coordinators, community members, and scientists.

Written by Gayle Ryley, Butler Elementary School, Ft. Lupton, CO, following the summer 1993 workshop. For further information contact Gayle at:

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Forth Lupton, CO 80621

Earth Systems Education at Marysville, Ohio, Middle School

The following contribution was adapted from an article written for the Autumn 1993 issue of the PLESE Newsletter, PLESE Note .... It demonstrates one of the ways in which Eisenhower funds can be used in a partnership between an institution of higher education and local school districts. It was written by Bill Steele, from Marysville Middle School, Marysville, OH.

The science program at the middle school had remained quite stagnant for many years. The standard "general, life, and Earth" sciences comprised our text–dictated curriculum in grades 6–8 respectively. One revision of curriculum amounted to nothing more than paraphrasing the table of contents from the text selected for that particular five to ten year period. It was apparent to all department members that the time for substantive change was long overdue.

A breakthrough was achieved in 1991 when our science staff became involved in a restructuring project with middle schools from nine districts and The Ohio State University. Realizing that we shared many problems (such as lack of time to plan together, not enough materials, and dictates from "on–high"—i.e. school boards, state departments of education, etc.), the discussion among participants then moved on to see what could be done about these concerns. The project itself was a tremendous help since the entire science department from a school in each district met for more than two days a month (one school day, one Saturday, and one after school meeting) to map strategies to create a more useful and responsive curriculum. The time was well spent. We quickly arrived at the consensus that there was much more to teaching science than those things listed in a textbook. We met with many individuals with expertise in both teaching and

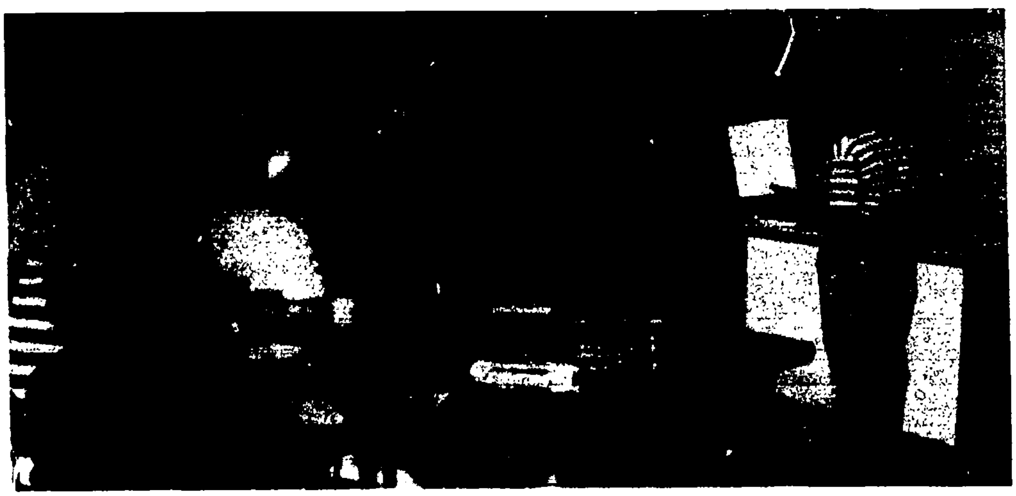
science disciplines. We visited other schools and science education facilities such as parks and museums. Finally, we had the confidence to create our own science program to fit the needs of our students.

The "seven understandings" of Earth Systems Education provide the focus for our middle school program now. While recognizing content as being important, we have decided to place a much greater emphasis on process skills that will provide our students with the tools to learn about the world they live in, and continue to use throughout their lives. A common theme at all three grade levels will be monitoring conditions at Mill Creek Park which is being developed as an outdoor lab facility for our district. Each grade will evaluate specific elements of the area as developmentally appropriate. Data will be shared among all grades along with the local elementary schools and the other two county school systems. Likewise, similar data collected at the county schools will be shared with us. Each grade level at Marysville Middle School will also develop some individual themes. "Trees and Forests" is a grade six theme. "Ecosystems of the USA" is one for the seventh grade and "Disasters: Man-made and Natural" is a representative title for a grade eight theme. While ten to fifteen themes per grade will be developed, not all will be covered each year. Depending upon teacher expertise, materials available and current importance, a theme may or may not be covered in any particular year. At the same time, themes may be added or eliminated for the same reasons. The unifying idea behind each theme at each grade level is how it will relate to all the Earth systems—atmosphere, biosphere, hydrosphere, and lithosphere.

We are still very much in the formative stages of developing our new program. The "Earth Systems Education" concept has provided both an impetus and a focus to allow comprehensive reform to occur. Over the next several years, the program should be completed. The ESE concept is dynamic enough to allow any science program to adjust to an ever-changing school and global environment.

Feel free to contact us if you have any questions. Bill Steele, Chris Hoehn, Laura Koke, Grayce Ann Kleiber, and Kevin Sampsel, the science staff at:

Marysville Middle School
833 N. Maple St.
Marysville, OH 43040



Teachers in a middle school workshop being held in Bill Steele's classroom in the Marysville Middle School.

Earth Systems Science Field Study in the Curriculum of the Laboratory School of the University of Northern Colorado

As a result of numerous national studies during the decade of the 1980s, science teachers have become acutely aware that traditional delivery of science content does not reach many students. Consequently, several curriculum change proposals have been brought forward (AAAS Project 2061, NSTA Scope, Sequence, and Coordination, Program for Leadership in Earth Systems Education). The latter one has been a nationwide K–12 curriculum reform philosophy piloted at teacher workshops at The Ohio State University and the University of Northern Colorado since 1990. PLESE was designed to infuse a systemic understanding of Earth into the curriculum content nationwide. Making the focus of the curriculum the planet on which we live helps to engage students where they are in the real world. This is opposed to trying to engage them in abstract or disconnected facts. Also, by focusing on students' feelings toward the Earth systems, the way in which they and others experience and interpret them, students are drawn into a systematic study of their planet. An aesthetic appreciation of the planet leads the student naturally into a concern for the proper stewardship of its resources; the PLESE approach capitalizes on students' awareness of their environment.

Trying to develop a concern for conserving the economic and aesthetic resources of our planet leads naturally into a desire to understand how the various subsystems function. A regard for how we study those subsystems also evolves. In learning how the subsystems function, students must master basic geology, physics, chemistry, and biology concepts. Moreover, other disciplines are invited into the classroom simultaneously, instead of willful avoidance. Students are encouraged to make connections instead of just considering each subject in a void.

The curriculum change process in the nation's schools looms as a formidable barrier to school restructuring. New strategies are needed to convince teachers that there are better ways to develop an integrated curriculum that is both exciting to students and academically rigorous. Considering the school curriculum as a study of the Earth and its systems does provide a new paradigm for a relevant, engaging, and rigorous approach for integrating the sciences with art, literature, social studies, language, and other disciplines. Using the nationally–tested philosophy of the Program for Leadership in Earth Systems Education (PLESE), the University of Northern Colorado Laboratory High School Science Department proposed to model the "systems thinking" approach with a science course called "Natural Science Field Study." Our idea was to study a local river, the Cache la Poudre, as a system, using an integrated, interdisciplinary approach. Instead of teaching biology, geology, chemistry, and physics separately, it was the intent of the new class to allow students to learn and understand science concepts by analyzing a river system out in the field. Once back in the classroom, students correlate the data to see how science disciplines are related to each other, as well as to all other disciplines. The premise of this effort is that solving global problems requires understanding the entire set of interactions between the various systems involved. The systems approach is in direct conflict with the reductionist approach that instructs students in one narrowly–defined discipline at a time, and discourages connections to other disciplines.

Students study the Cache la Poudre River at three to five different sites. At each location, the students analyze the chemistry of the water, collect and identify aquatic organisms, label, analyze, and map the substrata of the river, and measure and calculate the physical characteristics of the river systems. Students are also asked to observe the aesthetics and stewardship of the river sites. An overall map is constructed of the study location and correlations are made to understand interacting systems. Our purpose is to model a river system, the Cache la Poudre River, as a microcosm of global problems. By taking a concrete, local example of a study site, we have built a curriculum that can be transported back to each teacher's locality and applied to local systems in their communities. There is a growing concern that schools are not recognizing the importance of how basic subsystems of the Earth can be correlated to an understanding of finding solutions to global problems. There is a need to evaluate and restructure the middle and high school curricula to ensure that present and future citizens will understand systems in a holistic manner.

The Lab School's Natural Science Field Study class is a systematic approach to the Cache La Poudre River, which has been recognized by the Colorado Division of Wildlife, the Central Colorado Water Conservancy District, and the Colorado Audubon Society as an innovative and highly relevant course for today's students. This recognition has been emphasized by a strong interest from middle and high school teachers at national, regional, state and local presentations. For further information contact:

Raymond L. Tschillard
University of Northern Colorado Laboratory School
Greeley, CO 80631

A stretch of the Cache la Poudre River used in the UNC Lab School's Natural Science Field Study course.

A National University–based Program in Earth Systems Science Education

This article, written by Michael Kalb, Director of the Atmospheric Science Program of the Universities Space Research Association, appeared in the Spring 1993 issue of ***EarthQuest****.*

Many educators at the university level are currently developing undergraduate curricula in global change and Earth Systems Science, but their resources are often limited to what is available at their own institutions. To help overcome this problem, the Universities Space Research Association (USRA) and National Aeronautics and Space Administration (NASA) have inaugurated the University–based Cooperative Program in Earth Systems Science Education (ESSE). ESSE links faculty from 22 U.S. universities with each other and with NASA scientists toward the establishment of a national academic foundation for Earth Systems Science and global change studies, and for bringing new scientists with an interdisciplinary training into the field.

The ESSE program offers financial incentives to universities that are willing to participate cooperatively with other universities and NASA in curriculum development within a framework designed to overcome the traditional barriers to interdisciplinary science education.

Each participating university offers a survey course and a senior–level course in which faculty present Earth systems issues as a socially relevant, challenging, and important class of scientific problems. The survey course is meant to give the general student population an appreciation of the social, economic, and political implications of global change as well as a scientific understanding of the interrelationships between the climate and ecological systems. The senior–level course applies advanced concepts and analyses in a problem–solving, project–oriented environment. Its objective is to attract and motivate students to pursue graduate studies and perhaps careers in interdisciplinary global change and Earth science research. Senior–level courses are taught by at least two faculty members from different relevant disciplines.

Participating universities join in an organized exchange of scientists and faculty. To build on the strength in a particular university, visiting scientists from other universities and from NASA offer guest lectures in the undergraduate classes, present at least one seminar, and hold week–long discussions with the faculty, staff, students, and administrators. For this purpose, each university offers at least three of its faculty and scientists to a common pool, and each is encouraged to invite three visitors from this pool each academic year as well. ESSE provides logistical and travel support for these interactions.

A principal faculty coordinator has primary responsibility for the activities within his or her university. This person identifies potential teachers and faculty for the traveling pool. The coordinator also works with a NASA scientist who can contribute informally to the university's academic program by advising on class projects and experiments relevant to NASA missions, as well as by facilitating access to NASA data, technical material, and other resources. Each summer, the faculty coordinator and a teaching assistant have the opportunity to spend up to two weeks with their NASA affiliate at his or her center, and the NASA affiliate may spend up to a week at the university, as described above.

The 22 participating universities were chosen through proposals addressing the interdisciplinary strength of existing programs, faculty, and resources, and the institutional commitment to the development of interdisciplinary curricula. Eleven universities initiated the program in 1991, and 11 others joined the following year. The program is planned to continue through 1996.

Participating Universities and Faculty Coordinators

Johns Hopkins University, *George Fisher*
New York University, *Michael Rampino*
Northwestern University, *Abraham Lehrman* and *John Walther*
The Ohio State University, *Ellen Mosley–Thompson*
Pennsylvania State University, *Eric Barron and Jon Nese*
Princeton University, *Henry Horn*
Purdue University, *Ernest Agee* and *John Snow*
Rice University, *Arthur Few*
Rutgers University, *James Miller*

Stanford University, W. *Gary Ernst* and *Jonathan Roughgarden*
University of Alabama–Huntsville, *Richard McNider*
University of Alaska–Fairbanks, *Joshua Schimel*
University of Arizona, *Lisa Graumlich*
University of California, Los Angeles, *Richard Turco*
University of California, Santa Barbara, *Raymond Smith* and *Catherine Gautier*
University of Florida, *David Hodell*
University of Iowa, *Jerald Schnoor* and *Frank Weirich*
University of Minnesota, *Kerry Kelts*
University of New Hampshire, *Robert Harriss*
University of Wisconsin–Madison, *Francis Bretherton*
Utah State University, *Jeffrey McDonnell*
Washington University, *Raymond Arvidson*

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Earth Systems Science in the Liberal Arts Program of The Ohio State University

This is a contribution of Garry McKenzie, Department of Geological Sciences at Ohio State University. It is based on a paper he presented at a conference on the geosciences in the college curriculum sponsored by the American Geophysical Union, the National Association of Geology Teachers, and the Geological Society of America held in Washington, DC, in December 1994.

Earth Systems Science (ESS) is not a formal program or department in the University. The diverse nature of the subject and the fragmented structure of a university have influenced the development of this multidisciplinary subject so that components of it are available in several departments. The introduction to and principal focus for ESS resides in the Departments of Geological Sciences and Geography. Several courses for seniors cover aspects of Earth System Science in other departments. Often these courses are linked to a specific faculty member who has an interest in global problems.

The Department of Geological Sciences began to formalize the Earth System Science approach in the late 1980s when our Introductory Geology course became **Earth Systems I: The Geological Environment**. At that time of general curriculum reform, the Department of Geography developed **Earth Systems II: the Atmosphere**, which served as one of several options for a second course in a science sequence. The content of Earth Systems I, as with most courses, continues to evolve as new concepts, data, technology, books, and other teaching materials are available. We expect to see a major change in the content of Earth Systems I because of the recent availability of suitable textbooks on the subject.

Although these two courses lay the framework for our understanding of much of the Geosphere — specifically the solid Earth, hydrosphere, atmosphere, and the paleobiosphere — undergraduates are encouraged to gain a deeper understanding of the biosphere in one of the biology courses having an ecosystems approach.

Earth Systems I: Geological Environment. As with other introductory courses in the General Education Curriculum at OSU, the general goals are to improve student understanding of the principles and facts of the geological sciences, key events in the history of the science, scientific methods and techniques used by the science, and the technological, philosophical, and social implications of the discoveries in the discipline. Specific objectives within Earth Systems I are to:

1. introduce students to the concept of systems with flows of energy and matter, and the Earth as part of the solar system;
2. investigate the Earth as a system composed of subsystems — solid Earth (sometimes referred to as the lithosphere), hydrosphere, atmosphere, and biosphere;
3. improve student understanding of how the Earth works, particularly the processes operating in and on the solid Earth and the hydrosphere;
4. interpret the physical and biological history of the Earth and the nature of global environmental change; and
5. understand that humans depend on Earth resources for life support and are geologic agents involved in changing the geosphere.

Topics usually covered in lectures include: Earth in space; Earth as a system of subsystems; structure of the Earth; materials (minerals, rocks and environments of formation); geologic processes both endogenic and exogenic that shape the Earth's surface; rock, hydrologic, and plate tectonic cycles; processes as hazards; mineral and water resources; physical history of the Earth; history and evolution of life on Earth; global change — past and future; and impact of human population growth.

The content of the course is undergoing revision to provide an expanded view of the Earth as a system, with less emphasis on the traditional topics of physical geology. The current text is Montgomery and Dathe (1994) *Earth: Then and Now*; one text under consideration for adoption is Skinner and Porter (1995) *The Blue Planet: Introduction to Earth System Science*. The revised format will include lecture and labs, both involving practical exercises and improved visualization techniques.

Earth Systems II: Atmospheric Environment. Specific objectives of this course given in the Department of Geography are to:

1. introduce students to the nature of the atmosphere, weather phenomena, and climate;
2. investigate the interaction of the atmosphere with the hydrosphere and the lithosphere;
3. discuss atmospheric and human systems interaction; and
4. introduce students to the methodologies and tools of atmospheric sciences, and to the interdisciplinary approach.

Topics usually covered include: composition of the atmosphere, global energy budget, temperature, humidity, condensation, precipitation, winds, global circulation, air masses, severe weather, global climates, and climate change. Other topics, some of which may be covered in a particular class include: climate and landscape processes, global change, hydrologic cycle, small–scale human–atmosphere interactions, climate and vegetation, and extreme events and risk.

The current text is by Ahrens (1993), *Essentials of Meteorology: An Invitation to the Atmosphere*. The course is taught in lecture/recitation format with practical exercises and discussions.

Another option for a sequence after Earth Systems I is **Geology and The Environment.** This course provides a deeper understanding of geological processes and resources in the Earth system, introduces the importance of global environmental change, and addresses the impact of humans in the Earth system. Course content includes the essentials of environmental geology from a global environmental change perspective. Topics include geologic hazards (earthquakes, floods, volcanoes, landslides, subsidence and coastal processes), geologic resources (energy, water, metallics, and industrial rocks and minerals), management of solid and liquid wastes, environmental health, global environmental change (climate change, atmospheric pollution, biodiversity, etc.), regional planning and the environment, environmental law and global agreements, impact of population growth (the human system) on the environment, and long–range planning and scenarios for the geosystem. The current text is Keller (1992) *Environmental Geology*.

Together these three courses provide the basic level sequence in the Earth System Science curriculum at OSU — except for in–depth coverage of the human dimensions component of the Earth Systems. Although humans are part of the biosphere, the impact of humans as geological and biological agents is too great to be left as a subdivision of biosciences. The human sciences, including political sciences, social sciences, economic sciences, and health sciences, must be included in the study of the Earth System. Although population, politics and economics are mentioned in the basic Earth Systems courses, a deeper understanding comes from various "capstone courses" for senior undergraduates throughout the university. These courses, designed for less than 40 students each, are available in many departments and deal with "Issues of the Contemporary World." The nature of two such courses in the Departments of Geography and Geological Sciences are described below, followed by titles of other related courses that are appropriate for a student of Earth Systems Science.

In Geography, the applicable capstone course is **Integrated Earth Systems.** It focuses on atmospheric systems with lectures and laboratories. The lectures cover global change, systems, carbon and hydrologic cycles and greenhouse effect, deforestation, energy use, air pollution, meteorological and proxy climate records, remote sensing, deforestation, energy use,

and human population. The exercises include modeling, environmental insults, global warming, world population and the impact of the U.S. Federal Budget on the Earth System. The laboratory component uses the computer program, STELLA II, to examine causes and effects of global warming.

There is no formal capstone course in the Geological Sciences; however, **Population and Resources in Earth Systems** — an experimental course — will likely be used to fill this niche. As proposed, it will include lecture, discussion, and exercise formats. Topics include systems, global concerns, biogeocycles, global change, hazards and population, resources and population, biosphere and space stations, human systems, human population history, controls and carrying capacity, and metaphors and views of human population. Exercises will cover growth, evidence of environmental change, natural hazards, cycles and systems, links in systems, island game, concept diagrams, futures. Students will prepare a classroom exercise or a report. Although there is no adequate textbook for such a course, recent papers from journals will be assembled to use as a collection of readings. Several new exercises will supplement the available exercises on the topic of population.

There are several examples of advanced courses in other departments designed to improve one's understanding of Earth Systems Science. They include: **Antarctic Marine Ecology and Policy** (Zoology), **Problems and Policies in World Population, Food, and Environment** (Agricultural Economics), and **The Prehistory of Environment and Climate** (Anthropology).

Additional courses in Geological Sciences at the undergraduate level provide greater depth on aspects of the Earth System. These include **Energy, Mineral Resources, and Society, Water Resources,** and **Physical Oceanography and Marine Geology.** Other courses, at both the undergraduate and graduate levels, are offered in the School of Natural Resources and in several colleges, and new ones will be developed. Currently we are exploring a 2–credit hour course on global change to reach those students who would not otherwise get a course in the geosciences or in Earth Systems Science.

In summary, Earth Systems Science is the study of the total Earth and how it works. Professors in several science departments at The Ohio State University are in the process of developing and teaching a series of courses that, it is hoped, will provide a fuller understanding of the nature of the Earth system and its importance to that very small Earth subsystem, humans. Such is the basis for understanding natural and human–induced global and local change. It is our approach to understanding our life–support system — the spaceship Earth. In addition to advancing the science of Earth Systems Science, through these courses we expect to assist also in the education of the public and future leaders in business, industry, politics and the arts.

Eastern Center PLESE participants collecting Ordovician fossils at Caesar Creek, near Cincinnati, OH.

4

A Guide to ESE Curriculum Restructure and Implementation

Introduction

An Earth Systems Education curriculum implies one that is structured around several themes. The first is the **content** of the curriculum as influenced by the seven Earth Systems Understandings. These stand as long–term goals of student learning. Each component of an ESE program from Kindergarten through to the 12th grade should be designed to assist students in increasing the specific knowledge that lie behind each of these seven broad understandings. The major difference from the usual science frameworks is the emphasis upon Earth appreciation and stewardship, and the inclusion of a broader knowledge of the nature of science process; those represented as the historical and descriptive approaches used in studying the various earth systems.

The second theme is the **structure and organization** of the content of the curriculum. ESE emphasizes an interdisciplinary approach, including relevant information from each of the science disciplines where appropriate in the students' increasing understanding of Earth processes. It does not structure the curriculum according to the traditional science disciplines. In addition, teachers are encouraged to include content from the social sciences, language arts, and art and music where they can assist students in understanding Earth processes and their relations to these processes.

The third feature is the use of the **organizing principle of the Earth** for the entire science curriculum. Science is, after all, a study of Earth and its environment in space. All socially relevant information can be included in the curriculum if this focus is kept in mind when selecting science concepts and principles to include in teaching. If science concepts being considered for inclusion don't contribute substantially to the understanding of the individual and his/her relationship to the Earth Systems then they should be questioned for inclusion in the curriculum. Technology therefore, as it is used by the individual, assumes its proper place in the science curriculum. Rather than simply focusing on how technology is used in society and how science contributes to technological change, students are helped to understand what science can contribute to technology that is socially useful, and what the impact of the wide scale use of that technology can have upon the health of our planet. Technology is considered in the context of the Earth system in which it operates, and the influences it has upon that system.

The fourth theme is the **encouragement of cooperative learning climates**, as opposed to a competitive environment within the classroom. ESE classes are usually engaged in some type of cooperative or collaborative activity. The teacher is seldom in front of the group delivering information. Instead, students are engaged in productive group activity, obtaining and sharing information about the problem or Earth process under consideration. Assessment is on an individual basis. A student's grade will depend on the extent to which the student understands the content of the curriculum, not on the comparison of what one student knows with that of other students. Such assessments must be authentic; that is use procedures such as portfolios, rubrics and concept maps, not the traditional "end of unit" tests. In this style of assessment, students are asked to demonstrate their knowledge in a way that they will be required to do out in the "real" world, not by some contrived "objective" examination using multiple choice, true false or other type of artificial procedures.

Modern Science Content and Process
Interdisciplinary Structure and Organization
Earth as the Focus of the Curriculum
Cooperative Classrooms

Figure 1. Earth Systems Education Themes

To implement ESE requires attention to a modernization of the science content. Helping teachers become aware of the modern content and human context of ESE has been a major focus of the ESE program. Since the content and curriculum of science differs considerably across grade levels, a possible sequential approach has been outlined to demonstrate how "Earth-systematized" science curriculum might differ by grade level. In general, the methods of science would increase in complexity with higher grade levels, approaching a goal of having students be able to develop simple models and perform investigations to test their ideas about interrelationships (Figure 2). The locale of the science to be studied would generally progress from local to global across grade levels, although many combinations of global concepts with local examples are possible even at very early grades. An innovative addition to an Earth-systematized curriculum includes attention to values, both in terms of aesthetic expression and recognition of Earth values, both of which foster stewardship. The general scope and sequence model is shown in the chart below.

When using such a scope and sequence chart it needs to be understood that the specified values, methods and locales are not to be limited to the particular grade level in which they are specified. This level, instead, is to be seen as a locus around which each of them are developed. Global issues, for example, should be introduced at the elementary level, but they should not be the focus of attention there. Modelling can be introduced in the middle school, but most efforts in using that type of science method should be focused at the high school level when students have the proper background and maturity. Likewise those developed at an earlier level continue to be used and refined at subsequently higher educational levels.

Implementation Strategies

When the teacher goes into the classroom, all the content acquisition, context awareness, and grand plan for scope and sequence can become secondary to the day-to-day need for activities and resources to support a systems focus for teaching. This guide is designed to provide some of that support, as well as ideas for how the curriculum can be restructured with ESE as its core.

	Elementary		Middle School		High School
Values aesthetic stewardship	awareness expression	+	clarification expansion	+	evaluation decision making
Methods	sensing collecting classifying communicating	+	investigating predicting applying	+	experimenting modelling
Locale	home community	+	state national	+	global

Figure 2. Earth Systems K-12 Scope and Sequence

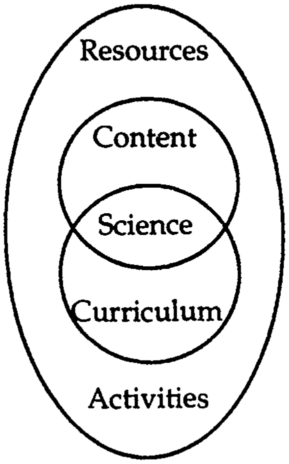


Figure 3. Interrelationships of ESE Curriculum Elements

Within the guide, experienced Earth Systems educators at all grade levels have provided examples of the resources they use to implement ESE. Where materials were perfectly suited to ESE they have been included intact, courtesy of their originators. Where materials were exciting but not quite inclusive enough to be an exemplar, those materials have been modified to demonstrate the process of adaptation of activities for infusion. The teachers have constructed checklists and evaluation devices they used, first to select activities to modify, then to identify gaps in those activities, and finally to assess the value of the activities as part of a unit plan.

This section of the guide relates to the strategies for implementing ESE in the classroom. As might be expected, when the traditional science curriculum paradigm is discarded, traditional science teaching strategies should also be scrutinized for their appropriateness in the new system. Indeed, in the lecture and textbook dominated classroom it is unlikely that a systems approach to science can be implemented effectively.

Classroom processes in an Earth systems setting will place the responsibility for learning directly on the learner. Students will be active participants in their education, rather than passive recipients of knowledge. Moreover, they will be responsible for teaching certain concepts to other students, with the idea that by sharing what they know, they gain ownership.

Learn It > Teach It > Share It > Own It!

Within the classroom, students will often be working in groups, perhaps in a cooperative learning situation or a collaborative one, with tasks that relate to solving complex questions. This emulates the way scientists themselves work, seeking the combined skills and knowledge of others and working together to reach solutions.

The students will be using diverse types of information sources, from current journals and magazines, to on-line databases, to CD-ROM information systems, to human resources in the community. Textbooks will be available as reference texts, but they will not control the flow of classroom events. There will be no "Outline the chapter and look up the definitions of the key words" type of assignments! Worksheets will ask for open-ended information, evidence of integration of information, and demonstration of interactions.

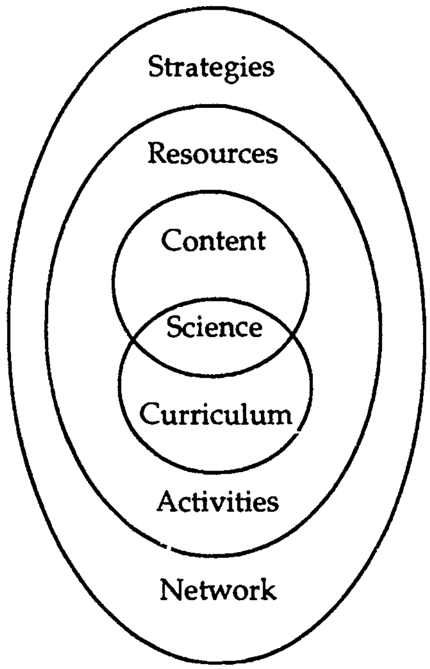


Figure 4. Relationships Among Expanded Curriculum Elements

In such situations, it is easy to see that communication skills are critical, from those of the teacher to the developing ones of the students. The kinds of questions asked by a teacher, for instance, will not be *'what'* questions very often. Instead, they will be *'how'* and *'why'* questions, with follow–up of *'have you considered,'* or *'what about a situation in which....'* Teacher questions will be challenging but not threatening, since the solution to problems or the expression of ideas are more likely to be sought rather then predetermined answers to set questions with the systems approach.

Student communication skills will be developed through their conversations within groups, challenging each other to provide the best input to the group process, and requiring clear communication to share the diverse types of input each contributes to the problem–solving situation. Early attempts at such communication may be playful and off–task, a phase that is typical as groups begin to function together for the first time. When the business of answering serious questions, exploring unique data forms, building an information base composed of each person's input becomes a necessity, most students will settle into a very responsible pattern of operating. Those who deal with group process identify a pattern of interactions that may be characterized as

Griping (or giggling!) > Groping > Grasping > Grouping

At the grouping stage, serious conversations within the group will draw out a wide range of questions about a topic, and numerous innovative and cooperative ways to approach a problem. It is amazing to listen in on group conversations when this stage is reached; student communication often demonstrates deep thinking and serious attention to task. When the students finally grasp the process and attend to the business of problem solving, their example could be useful to many adult groups!

Infusion Guide

Earth Systems Education is based upon a set of seven understandings that are arranged to help educators develop activities and units that are arranged around the Earth's spheres of the Hydrosphere (water), the Lithosphere (rock), the Biosphere (life) and the Atmosphere (air). Within these spheres two other spheres have been intertwined. Space, the exosphere, has been included within the atmosphere while the cryosphere, the world of ice, has been included within the hydrosphere.

Three steps have been identified to help educators Earth–systematize their lessons, classroom, and teaching style. These steps can be remembered through the acronym **AIR:**

Awareness
Infusion
Restructuring

Awareness

Awareness is the first level of understanding in Earth Systems Education. In becoming aware of the potential of Earth Systems Education, the educator begins to understand how the Earth systems framework can be applied to the everyday teaching situation and begins the process of empowerment over the curriculum. As an educator becomes aware of the Earth System concept and its potential use in one's own classroom, the importance of integrating the sciences, as well as other subject areas within the classroom, becomes more obvious. The unique structure of the ESE framework provides an easy method for integration.

The second level of Earth systems awareness is when the process of sharing ideas with other educators begins. The following list has been generated by teachers who have successfully used one or more of these suggestions to communicate the value of ESE to administrators and other teachers. It is a slow, gradual process that is motivated by one's own involvement and enthusiasm in Earth Systems Education.

Building Level

- Share publications about Earth Systems Education.
- Make spheres and understandings visible (halls, lounge, library).
- Open your room to other teachers for informal observation.

- Engage in informal rap sessions.
- Exchange classroom visitations with other teachers.
- Show a slide presentation at a faculty meeting.
- Present a mini-lesson workshop.
- Share your resources; make them visible.
- Team teach a lesson or unit.
- Incorporate ESE into your team situation.
- Demonstrate an activity in another classroom.
- Share ESE with student teachers.
- Design an ESE poster contest.
- Plan a field trip for teachers.
- Use ESE framework for Parent Science Night.
- Include an ESE "hook" in the course list.

District Level

- Take an administrator/coordinator to lunch.
- Take an administrator/coordinator on a field trip, hike, or bike trail.
- Make a presentation at a PTA meeting.
- Make a school board presentation.
- Write a formal proposal including the rationale for your proposal for introducing ESE to your district.
- Obtain letters of support.
- Give a district-wide teacher/administrator workshop.
- Present a workshop for credit.
- Alert local media when you are doing an exciting science activity.
- Send articles to local media.
- Be a representative on the district science curriculum committee.
- Present at the state or regional science convention.
- Send students to state-wide workshops. Have them incorporate ESE into their presentations to other classes.
- Invite an administrator/coordinator to observe a model lesson.

Infusion

Infusion is the process in which an educator incorporates activities into an existing repertoire of teaching activities. This process follows very closely the awareness stage of ESE. As an educator becomes aware of the Earth systems and the seven understandings, the next step is to begin to find ways to infuse these ideas within a classroom. Often this takes the form of an activity that an educator holds near and dear and feels comfortable with. The following list is a set of criteria that can be used to help select appropriate materials to be Earth-systematized. In addition we would suggest you incorporate the ideas presented in the article entitled "What Do I Do with All These Activities?" by Brownstein, Rillero, and Feldkamp-Price which follows this guide.

The activity should be:

- scientifically correct
- familiar to you
- student centered
- hands on
- minds on
- relevant to the concept being taught
- grade level appropriate
- appropriate for time and resource limits
- geographically feasible
- suitable for integrating with other science/subject areas
- easily evaluated with possible authentic assessment
- supported with background information
- social skill oriented
- experiential in its approach
- designed to be gender neutral
- multiculturally appropriate
- designed to help students answer important questions
- developmentally appropriate, and
- appropriate for use in the development of communication skills.

Once an activity has met most of the above criteria it can be Earth-systematized so that each of the Earth Systems Understandings and spheres can be incorporated into the existing high quality activity. Infusing the Earth systems into activities is a rather simple process which includes the following steps:

- Select an activity based upon the above criteria.
- Assess the activity for Earth-systematizing.
- Develop questions for those of the seven Earth Systems Understandings (ESUs) that relate to the selected activity. These questions will later guide student inquiry.
- Brainstorm interactions between the Lithosphere (rock), Hydrosphere (water), Biosphere (life) and Atmosphere (air).

- Write or rewrite the activity to include more spheres and understandings, and more of the learning process elements of ESE, such as cooperative learning and experiential learning.
- Always give credit to the source of the activity. If it is copyrighted and you wish to distribute copies to students or other teachers, you must get permission from the publisher.

'Earth–systematize'

The term **'Earth–systematize'** was coined to reflect a methodology behind the selection of activities that reinforced and reflected Earth Systems Understandings and are arranged using spheres as an organizing principle. The term suggests the idea that activities used in an Earth Systems approach have similar appearances and a methodology that is unique. When an activity is Earth–systematized, it undergoes a metamorphosis or change. This change takes place using the format listed within this chapter. To facilitate the user in efforts to infuse an activity into the classroom a series of forms have been devised. They may be used in a variety of ways and require only a small amount of time to complete. Although it is a goal to include as many spheres and understandings as possible into an activity, it is important to note that it is not a requirement to have every sphere or understanding represented. Regardless of which method is used to Earth–systematize the selected activity, the following points must be emphasized:

- activities need to be of high quality for answering science questions,
- activities should lend themselves to integration between the traditional science disciplines of biology, chemistry, earth science and physics,
- some activities should also demonstrate relationships to disciplines such as mathematics, social sciences, art, and music.

Infusion steps

To begin the process of Earth–systematizing an activity, the authors have found the following methods to be quite useful.

Step 1: Complete the *Activity Assessment Guide* in as much detail as possible. Writing a brief description of the activity helps to clarify its objectives. After determining the spheres and Earth Systems Understandings (ESUs) already in the activity, engage in a brainstorming session with at least one other teacher to expand the activity into incorporating other spheres and ESUs. The Activity Assessment Guide also includes sections for indicating the science concepts covered (Content Core), and procedures for evaluating students outcomes.

Step 2: Using the *Activity Question Development Form* begin to formulate questions for each ESU to help guide both the teacher and student as they proceed through the activity. This form is not intended to force an educator to write a question for every understanding, rather it is intended to facilitate the Earth–systematizing of the activity. Activities that include multiple ESUs should, however, have several questions that help guide the learning. When writing questions think of them as educational objectives in question format. Avoid questions that can be answered yes or no, and those with a defined list as an answer.

Step 3: The *Activity Interaction Web* is designed to facilitate the search for the various interactions found within the Earth's subsystems. Interactions play a key role in activities being Earth–systematized. The form can be used as a way to check for interactions after an activity has been rewritten. The diagram is designed to have the educator write in and draw arrows between the various Earth systems interactions found within the activity. Educators who prefer to list interactions may find the bottom half of this form quite useful.

Step 4: The *Activity Evaluation Form* is simply a way for the educator to double check the activity for science concepts, science processes, educational objectives, and assessment methods needed to insure quality in the revised form of the activity. It is best used after the activity has been developed and pilot tested.

Restructuring

Unit Development

Once an educator has learned to infuse single activities into the classroom he or she is ready to begin rewriting complete units following the Earth Systems framework. This process follows closely the steps for infusing individual activities. Unit development should include the following steps:

- Select a topic.
- Develop questions using the question development form.
- Brainstorm interactions within and between the Earth's spheres.
- Brainstorm science concepts, content, and processes involved.
- Select or develop activities that attempt to answer the unit questions.
- Assess each activity using the activity infusement forms.
- Assess the unit for the Earth Systems Understandings and spheres.
- Fill in the gaps found through using the unit assessment form.
- Restyle activities, if necessary, to fit a cooperative learning or experiential mode.

The activity forms can be modified to help develop an Earth Systems unit by simply changing the **Activity** title to **Unit**. Once activities have been selected and Earth–systematized, the structure of the entire unit can be examined using the Unit Summary form that follows the Activity forms at the end of this section. An exemplary ESE unit will have materials for all the subsystems and ESUs, will address multicultural issues, and will be taught using strategies that facilitate experiential and cooperative learning. The final step in developing an ESE unit is:

- Assess the unit for ESUs and Earth systems spheres.
- Assess the unit for possible inclusion of multicultural issu
- Ensure that you've included experiential or cooperative learning approaches in the unit.
- Fill in any gaps found within the unit.

Ron Armstrong, Associate Director of the Eastern PLESE Center, discusses a display of Ordovician fossils at Caesar Creek Lake with participants.

Forms for Activity and Unit Development

ACTIVITY ASSESSMENT GUIDE

1. Title of activity: ______________________________

2. Write a brief description of the activity. What is its purpose and goal?

____

____

3. Circle the system(s) addressed in the activity.

Life **Water** **Air** **Rock**

4. Circle the understandings that are in the activity.

1 **2** **3** **4** **5** **6** **7**

5. Brainstorm a list of possible extensions or activities that might incorporate the understanding not addressed in this activity.

____

____

____

Science Content Core

____

____

____

____

Evaluation Procedures for Activity

____

____

____

____

ACTIVITY ESU QUESTION DEVELOPMENT

Activity Title: ______________________________

Activity Focus Question: ______________________________

Understanding #1: Earth is unique, a planet of rare beauty and great value.

Question: ______________________________

Question: ______________________________

Understanding #2: Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

Question: ______________________________

Question: ______________________________

Understanding #3: The development of scientific, thinking and technology increases our ability to understand and utilize Earth and space.

Question: ______________________________

Question: ______________________________

Understanding #4: The Earth system is composed of interacting subsystems of water, rock, ice, air, and life.

Question: ______________________________

Question: ______________________________

Understanding #5: Planet Earth is more than 4 billion years old and its subsystems are continually evolving.

Question: ______________________________

Question: ______________________________

Understanding #6: Earth is a small subsystem of a solar system within the vast and ancient universe.

Question: ______________________________

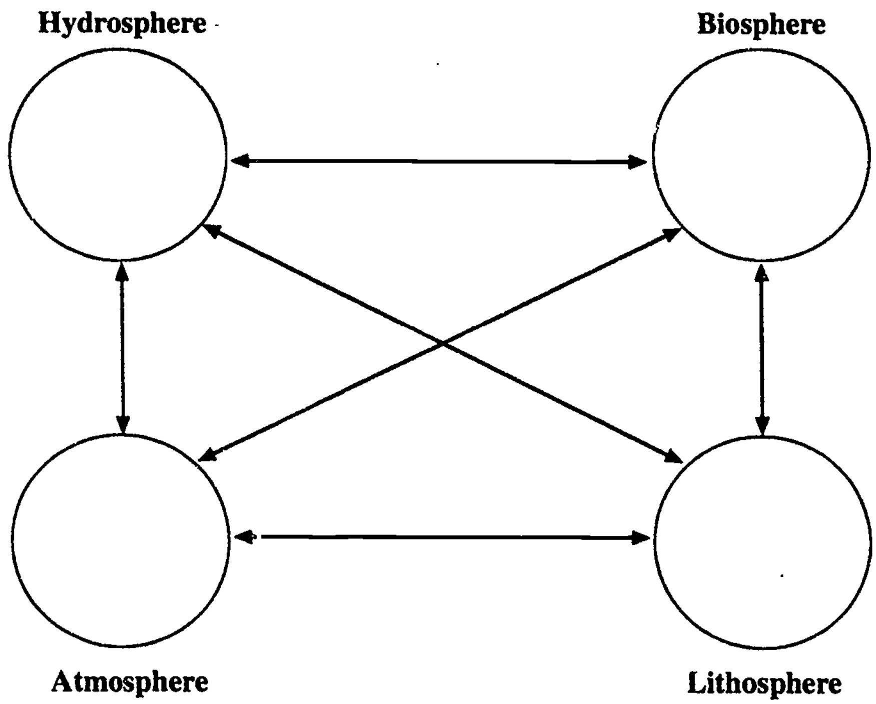
Question: ______________________________

Understanding #7: There are many people with careers that involve study of Earth's origin, processes, and evolution.

Question: ______________________________

Question: ______________________________

ACTIVITY INTERACTION WEB



Lithosphere affects Biosphere
1.
2.
3.
4.
5.

Lithosphere affects Atmosphere
1.
2.
3.
4.
5.

Lithosphere affects Hydropshere
1.
2.
3.
4.
5.

Hydrosphere affects Biosphere
1.
2.
3.
4.
5.

Hydrosphere affects Atmosphere
1.
2.
3.
4.
5.

Hydrosphere affects Lithosphere
1.
2.
3.
4.
5.

Biosphere affects Lithosphere
1.
2.
3.
4.
5.

Biosphere affects Atmosphere
1.
2.
3.
4.
5.

Biosphere affects Hydrosphere
1.
2.
3.
4.
5.

Atmosphere affects Biosphere
1.
2.
3.
4.
5.

Astmosphere affects Lithosphere
1.
2.
3.
4.
5.

Atmosphere affects Hydrosphere
1.
2.
3.
4.
5.

ACTIVITY EVALUATION FORM

Activity Title: ______________________________

Activity Focus Question(s) (one for each part): ______________________________

____

____

Science Concepts (list major science concepts in this activity): ______________________________

____

____

____

Process(es) Included:

________ Sensing	________ Investigating	________ Communicating
________ Collecting	________ Predicting	________ Experimenting
________ Classifying	________ Applying	________ Modeling

Approaches Used:

________ Inquiry	________ Outdoor Based	________ Multiple Learning Styles
________ Integration	________ Multicultural	________ Collaborative Learning
________ Teacher Facilitated	________ Technology	

Locale:

________ Local ________ State ________ National ________ Global

Earth System Understandings (ESUs) (list numbers):

____

Science Objectives:

____

____

____

____

Evaluation Procedures:

____

____

____

____

UNIT SUMMARY FORM

Unit Name: ____

Unit Question: ____

Use this chart to identify which systems and understandings are present in the unit. Circle the systems and understandings present in each activity. Use the resulting information to develop student centered activities that will address the weaknesses found in the unit.

Activity Name	Systems	Understandings
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7
______________	Air Life Rock Water	1 2 3 4 5 6 7

Instruction or Learning Procedures

Determine the approximate proportion of class time spent in each of the following modes:

_________ Cooperative learning
_________ Other group learning activities
_________ Experiential learning
_________ Outdoor or field experiences
_________ Other Learning and Teaching Modes (list)

Evaluation Procedure for Unit

____

____

____

____

A HIGH SCHOOL EXAMPLE: INFUSING EARTH SYSTEMS UNDERSTANDINGS INTO RESTRUCTURED CHEMISTRY AND PHYSICS COURSES

SUGGESTIONS

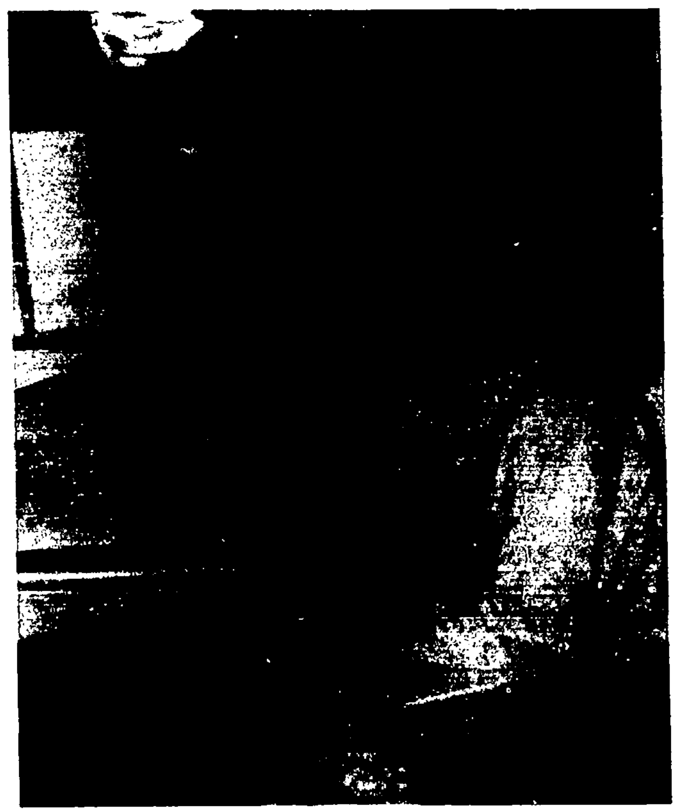
The process of restructuring science curriculum at the high school level presents various hurdles to overcome to achieve success. These hurdles are especially high for the physics and chemistry courses often seen as the elite courses in science and therefore the ones that are crucial for successful college entrance and subsequent career success. Several of the major hurdles are:

- obtaining the support of colleagues, administration, school board, and parents; many of whom achieved success in these courses
- determining how restructure fits in with college or university entrance requirements
- educating appropriate personnel (counselors, administrators, etc.) so that students are not confused about the appropriateness of choosing Earth Systems courses as a lab classes rather than traditional courses
- convincing people that this program is more than just a substitute for the school's lower track science courses—that it is appropriate for all levels
- bridging the chasm between teacher directed, content oriented teaching approaches and student directed, process oriented learning—that is, breaking the paradigm that high school teaching is best done by lecture and teacher directed lab experiences
- informing post secondary institutions about Earth Systems Education so that courses are recognized as appropriate prerequisites for admission to such institutions
- discipline related concepts in an Earth Systems approach

To overcome such hurdles you will need to enlist the support of sympathetic administrators and counselors. They can identify sources of information and useful strategies and take some of the load off of the shoulders of teachers in effecting change.

Developing lessons that follow the Earth Systems model takes large amounts of time. Many high school teachers find the task overwhelming. Attacking it in smaller increments (e.g. a unit at a time), enlisting other science teachers and those in other disciplines to help develop lessons that cross curricula, and coordinating resources found inside and outside school are key strategies to consider. You should also initiate efforts to find funding that can release teachers to work on the development of materials. Larger school systems will often have an administrator charged with developing proposals and seeking grants from outside agencies, such as state and federal agencies and private foundations. A local or state university can also often assist in this effort. Science or science education professors can help in securing funds for teacher enhancement activities that also result in the development of new curricula.

To get your thinking started as to how you can begin to change your chemistry and physics courses to reflect the ESE approach the following two scenarios have been developed by several chemistry and physics teachers.



BESS student using computers for ESE integrated science activities

Chemistry Scenario

Earth Systems Education and Chemistry have many interconnections. Much of the history of Chemistry stems from trying to solve problems related to our environment, how to isolate, purify or reproduce a particular substance, how to locate and extract a needed element or compound from a mineral, etc. As such, teaching Chemistry from an Earth Systems approach seems logical. The following three examples show how Earth Systems questions and Earth materials can be used to teach key Chemistry concepts.

1. How Can We Differentiate Between Elements and Compounds Using Earth's Materials?

Concepts to be taught:

- physical properties
- substances
  - pure
  - impure
- homogeneous
- heterogeneous
- mixtures
- elements
- compounds

Possible approach to learning:

Obtain various samples of rocks and minerals. Have students examine them for similarities and differences and attempt to classify them based on their own derived categories. Have students discuss their findings and compare the various ways different groups of students classified their samples. Then have students sort through the samples based on a chemist's approach to substance classification and compare this classification with their own methods.

2. How Does One Distinguish One Mineral Or Rock from Another?

Concepts to be taught:

- physical properties (intrinsic and extrinsic): density , cleavage, color, luster, streak, hardness, specific gravity, crystal shape
- chemical properties
- significant figures in measurement

Possible approach to learning:

Use the same samples of rocks and minerals to measure physical properties and to determine chemical properties. Challenge students to come up with their own explanations as to why rocks with the same collection of minerals appear so different and have different names.

3. What Are the Most Abundant Elements on Earth and How Does Such a Small List of Elements Create Such a Wide Variety of Rocks and Minerals?

Concepts to be taught:

- element names and symbols
- compounds
  - naming
  - classifying: silicates, oxides, sulfides, carbonates, sulfates, phosphates
- chemical reactions
  - salt formation
  - solutions and properties
- states of matter
  - temperature
  - pressure
  - crystallization
  - evaporation
- separation techniques

Possible approach to learning:

Make saturated solutions and let evaporate to crystallize. Compare crystal structures. Perform various reactions (single and double replacement, synthesis, and decomposition) and relate to the formation of different minerals. Attempt to separate a rock into its various components or combine various substances to form a rock-like mixture.

Physics Scenario

Physics has many concepts applicable to the Earth: radiation, flow rates, planetary movement, light waves, longitudinal and transverse waves associated with earthquakes, provide just a few examples. Some typical Physics topics have been illustrated below using an Earth Systems approach. These examples are certainly not exhaustive of Physics concepts, but are noted as ways to use Earth Systems in Physics.

1. How Can Geothermal Energy Be Used For Heating?

Concepts to be taught:

- heat
- boiling point
- calorie
- coefficient of cubic expansion
- conduction
- heat transfer
- thermal energy
- law of heat exchange
- insulation
- joule
- kilo calorie

Possible approach to learning:

Use cooperative learning and divide students into groups to study geothermal heating. Students should investigate how geothermal heating works, where the energy ultimately comes from, the environmental hazards and benefits of geothermal heating, etc. Studies of geysers, hot springs, and other naturally occurring forms of heating should be compared. Challenge students to decide on the best geothermal heating device to heat a typical home using the least amount of alternative forms of energy. Have students compare costs of heating the home using gas, electric, and geothermal sources. Students can form review panels to advise role-playing potential home buyers which form of heating is best. Students could also produce pamphlets advertising the various forms of energy. Related topics could range from reactions that produce the sun's energy to the energy produced by the Earth's interior.

2. What Physics Concepts Are Used to Determine the Date of a Rock Formation or Fossil and to Estimate the Age of the Earth?

Concepts to be taught:

- radioactivity
- radioactive dating
- half-life
- nuclear reactions
- convection—regarding movement of plates
- radiation
- magnetic fields
- electromagnetic waves

Possible approach to learning:

Conduct simulated experiments on radioactive half-life, graphing the functions of time and number of remaining particles. Divide students into groups to investigate the various types of radioactive dating techniques being used today and then form a panel discussion of "experts" who will use the knowledge gained to determine the age of a particular rock formation. Possible discussions could include the concepts described above and should correlate to methods of dating using magnetic pole reversals.

3. How Would One Use Physics to Estimate How Long It Would Take for a Balanced, Undercut Boulder to Fall?

Concepts to be taught:

- center of mass
- gravity
- point of suspension
- erosion rates
- force of impact

Possible approach to learning:

Show students a picture of a balanced rock or boulder that is being slowly undercut by wind or water. Challenge them to determine the size of the rock (given scaling), the mass of the rock (determined from measurements of density of a smaller sample of the same type of rock) and the approximate location of the center of mass. If given pertinent data such as the height of the rock and the rate of undercutting, students can estimate the time it will take for the rock to be undercut enough to fall.

Summary

These are some modest suggestions on how to get started infusing an Earth Systems approach into chemistry and physics curricula. One of the most important first steps would be to evaluate current textbooks and consider changing to one that is more supportive of an Earth Systems approach. Two that come to mind are *Chemistry in the Community* developed by the American Chemical Society, and *Conceptual Physics* written by Philip Hewett. Both depart from the traditional academic approach to their subjects. It would be relatively easy to develop Earth Systems oriented courses by supplementing these two texts with appropriate materials.

Choosing Science Activities for Your Classroom

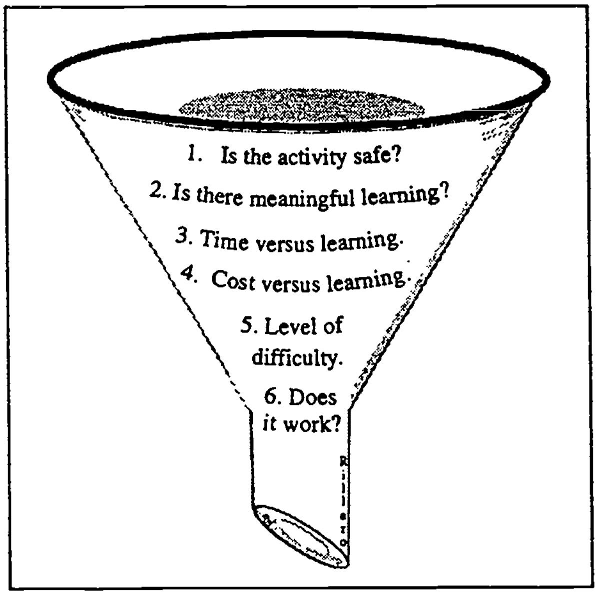
What Do I Do with All These Activities?

ERICA M. BROWNSTEIN
PETER RILLERO
BETSY FELDKAMP-PRICE

With the thousands of science activities available, how does a teacher select the ones that are appropriate for his or her classroom? Many teachers use a trial-and-error approach, but some of the most productive teachers use effective strategies for choosing good activities. To aid educators in this selection process, we have created a set of guidelines for choosing science activities. These guidelines were produced through a synthesis of learning-theory literature, our own experiences, conversations with inservice teachers, and interviews with preservice teachers.

In the relevant literature, many articles address specific items to consider when choosing an activity, but there does not seem to be an overarching approach. In this article, we provide these specific items in a single protocol through the Science Activity Filter (SAF; see figure). No one of the preservice teachers we interviewed mentioned all the components of the SAF, but each category was offered in at least one interview.

The SAF has six categories for determining the appropriateness of an activity; they are as follows.



Peter Rillero

The guidelines of the Science Activity Filter. The order of the guidelines provides a useful protocol for evaluating science activities for their value in the classroom.

- Is the activity safe?
- Does the activity stimulate meaningful learning?
- Is the time needed for the activity balanced by the amount of student learning?
- Is the cost of the activity balanced by the amount of student learning?
- Is the level of difficulty appropriate for the students?
- Does the activity work?

The SAF enables a classroom teacher to sort through a variety of available science activities and determine appropriate ones. Many teachers might assume that published activities are effective in developing thinking skills, but this is not always the case (Shepardson 1993). The burden of selection should rest with the

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educator, and the SAF guidelines can be an effective aid in this process. The use of reliable, teacher-based sources, such as those found in *Science Activities, Science and Children,* and *The Science Teacher,* can also make selection easier.

What follows is a discussion of the SAF and an illustration of its effectiveness in choosing science activities. Some sample activities are filtered out when using the SAF, whereas others pass through. A few of the unsuitable ones can be modified to enable them to pass the guidelines. It is important to stress that there are very few activities that are perfect for everyone or every situation. For example, some safety issues are highly context dependent, as we will demonstrate in the following section.

Is the Activity Safe?

Safety should be the foremost consideration when choosing a science activity. The fact that an activity appears in a published work is no guarantee of its safety for classroom use (Manning and Newman 1986). For example, a hotplate may be required during an activity in which Benedict's solution is used to test for glucose. This activity could be safe in a classroom that has volunteers to assist the students in the procedures, but it would not be safe in a classroom without assistants.

The placement of the safety precautions within a published activity is important, as well. Anderson, Beck, and West (1992) noted that sometimes a given safety instruction is positioned after the relevant procedure. For instance, in one published activity they examined, a student is directed to insert glass tubing into a rubber stopper and warned in the *next* step to use glycerin and a towel while inserting the tubing to minimize the danger of breaking the tubing and getting cut. Safety warnings need to be given *before* instructions for performing an activity, as most students do not read ahead.

Does the Activity Stimulate Meaningful Learning?

After an activity has been judged safe, the next logical step is to evaluate the degree of meaningful learning that the activity is likely to impart. As Padilla noted, "Without meaningful activities, science becomes just one more verbal learning experience" (1981). Activities should allow students to construct their own knowledge and build on previous experiences. For meaningful learning to occur, science activities should fit within the students' level of cognitive development and be relevant and useful.

One published activity asks children to construct and use a salt-and-flour–paste volcano (Tolman and Morton 1986). A funnel is buried in the middle of the volcano with a rubber hose extending out the side. The children then fill the hole with puffed cereal, blow air through the hose, and watch the cereal fly. The activity keeps the students (and the janitor) busy, but any conclusions that the students construct will probably lead to misconceptions. It is not air that pushes lava out of a volcano. The cereal blown out accurately represents neither the flow of lava nor the characteristics of an ashfall.

Another activity, suggested for preschool children, recommends explaining both the change of seasons and the process of night and day in one continuous lesson (Harlan 1992). Although both of these abstract concepts represent natural cycles, they have scientifically different explanations that are beyond the abilities of the average preschooler. Activities should be matched to the developmental level of the students.

Meaningful learning need not be limited to the cognitive domain: Psychomotor and affective objectives are also important goals. The ability to manipulate science apparatus is an important psychomotor objective, and students' enjoyment and valuation of science are important affective goals. When choosing an activity, Barry, a preservice teacher we interviewed, stated that children's interests should be considered—"The students should like and be enthusiastic" about an activity.

Is the Time Needed for the Activity Balanced by the Amount of Student Learning?

If the activity has passed the safety and meaningful-learning criteria, then the educator must next consider the time/learning balance (Rutherford 1993; Teters and Gabel 1984). Kara, a preservice teacher, said "Because there is a constraint on time available, activities may need to be modified to [adjust for] limitations." Each activity should be evaluated for how much student and teacher time it takes up. Is the time consumed in balance with the value of the learning experience?

Some projects are very labor intensive. At times, the science principle can be buried if the activity is too elaborate. For example, one activity that we found requires the students to make a model of a space shuttle (Vogt 1991). The children construct the frame from egg cartons, cardboard, tape, and glue; cover it with papier maché; and then paint the model. An elementary Montessori class took four hours to construct the shuttle. This did not include the time needed for the shuttle to dry. Although the shuttle may be fun to create, some educators may not have the classroom time to use it as written. An adaptation of the project may include assigning the project to be completed at home. Then the teacher can meet her classroom objectives within the limited available class time.

Not just student or class time should be used efficiently—teacher time should be used effectively as well. It is important, when evaluating an activity, to determine how much preparatory time is required of the teacher. The issue is once again one of balance, with the teacher measuring how much time is avail-

able and comparing that to the potential learning outcomes of the activity. One published activity encourages students to make spider webs (Beck 1992). To prepare for this activity, the teacher has to assemble a large frame structure for the students to create spider webs on. Although this activity encourages problem-solving skills, a teacher has to decide if he or she has the time to assemble the necessary equipment.

Another time question to consider is: Does the activity keep the students busier than the facilitator? If a teacher's time is monopolized in material-management tasks, then she or he may not be able to help students construct their own learning experiences.

Is the Cost of the Activity Balanced by the Amount of Student Learning?

If the above criteria have been satisfied, then the next important factor to consider is cost compared with learning potential. One preservice teacher named Sarah noted, "It should not be too expensive to buy the materials needed. unless it is a long-term purchase." Balancing cost and student learning is unique for each teacher because budgets vary from school to school. Economic considerations have to be weighed to determine if the school or the teacher is willing to pay for the activity. An interpretation of an activity requires that the cost be balanced with the benefits of learning.

An expensive activity is not always necessary to achieve useful results. For example, students may wish to examine the parts of an insect. Although a dissecting microscope would be ideal, a simple magnifying glass will often suffice. Each professional should weigh the monetary costs against the instructional objectives.

Is the Level of Difficulty Appropriate for the Students?

Having passed an activity up to this point, it is now necessary to consider the level of difficulty in relation to the age and abilities of your students. Is the activity too complex or tedious for the students? If an activity bogs students down in details, they will likely feel that the end result is meaningless or trivial (Thorndike 1920). For example, performing titration experiments to determine the acidity of a solution can be exciting, but if a young student has to make many precise measurements, the excitement may be lost. The teacher should cater the precision of the results to the age- and ability-level of the children.

Are the skills required too difficult for the students? A microscale activity that uses small pieces of equipment and tiny amounts of chemicals to demonstrate pH is not appropriate for children who do not possess the motor skills necessary to perform the procedure. Instead, an educator may use common items such as oranges, vinegar, and milk.

Does the Science Activity Work?

If the activity has made it through the first five points of the SAF, the final and most time-consuming evaluation is deciding whether the activity does what it professes to do. The best way to find out if an activity works is to try it. We have found that some published activities simply do not work, and we suggest that all activities be tried before they are used in the classroom. Their effectiveness may not be at all apparent from the printed directions. For example, one published example offers instructions for creating an aluminum-foil–covered umbrella to improve the reception of a radio. When the experiment was tried, no difference in radio reception was found. Experts who were consulted to explain this failure stated that the umbrella would have to measure *thirty meters across* to produce an improvement in reception!

The SAF puts this criterion last because by this time many activities should have been filtered out according to the previous criteria. If an activity does fail to work when tested, it may not be a total loss. Failure may be due to poor activity design, faulty equipment, or impotent chemicals. When an activity does not work, the teacher can look for help from a convenient source, such as another teacher, a professional journal, a member of the district science education office, or a scientist.

Final Thoughts

Even the best activities need to be evaluated and modified by each teacher for particular teaching situations. Finding an interesting activity and then having to filter it out is not a failure. Many activities need to be considered before the excellent ones are discovered. Experienced science teachers build up stores of effective activities.

A teacher can also use the SAF guidelines as a framework for modification of activities. Preservice teachers in our classrooms use the SAF to adapt activities for particular age groups. At first, it is a time-consuming task, but after a few trials, the future educators are able to pick up an activity for any age and easily adapt it to their students' abilities. This demonstrates that when an activity does not make it through the filter, it often can be altered by the professional classroom teacher.

Our experience shows that the six guidelines of the Science Activity Filter are useful in weeding out potentially inappropriate activities. Any activity considered for classroom use needs to be evaluated for safety, meaningful learning, time/learning balance, cost/learning balance, level of difficulty, and feasability. Choosing the best classroom science activities will help use resources effectively, minimize discipline and safety problems, and maximize learning.

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5

Teaching Approaches in an Earth Systems Classroom

This section is based largely on an article entitled "Constructivist Approaches to Teaching" originally written for the guide by Charlene M. Czerniak of the University of Toledo. At the end of the section you will find a series of articles on alternative assessment practices that are reprinted from an issue of **Science Scope** *published by the National Science Teachers Association.*

As science teachers, we are all concerned with helping students learn new knowledge and skills related to the Earth's systems. Learning, however, is a complex event, and finding the most effective way to help children learn is the essence of what makes a good teacher. David Ausubel (1968), an educational psychologist, stated that, "The most important single factor influencing learning is what the learner already knows." Joseph Novak and Bob Gowin, professors at Cornell University, stress that a primary concept in Ausubel's theory is meaningful learning. That is, in order for learning to be meaningful (as opposed to rote memorization), students must choose to relate new knowledge to relevant concepts they already know. This might require learning information, or perhaps unlearning some information and restructuring new knowledge.

Recently, a term "constructivism" has been used to explain what happens as children learn. According to Constructivist theory, knowledge is constructed by the learner based upon his or her experiences in the world. When the learner is dissatisfied with his or her current conceptions of the world, she/he must adapt understandings in order to make sense of the world. This transition in conceptual understanding can only be made by the student. However, conceptual change is facilitated when the student interacts with others, discusses new ideas, explores hands–on materials, and relates this new knowledge to pre–existing understandings about the world. The teacher can use a variety of instructional strategies to help facilitate conceptual change and understanding. As you might suspect, traditional methods of evaluation are not consistent with measuring conceptual change. In this section, we will explore strategies for assessing prior knowledge, instructional techniques that facilitate conceptual change, and methods of evaluation that are compatible with Constructivist teaching.

Assessing Prior Knowledge

There are many ways that a teacher can assess students' prior knowledge. These can vary from traditional pretest measures such as pencil and paper tests to observations made of students in the classroom. Regardless of the method used, the primary goal is to determine what students already know and where they may have alternative conceptions or misconceptions (conceptions that are not consistent with those accepted by scientists) about scientific knowledge. For example, a young child may believe that leaves cause wind because every time the wind is blowing, leaves on the trees are moving. An older student might believe that blood is blue because it looks blue when one sees the veins on the arms or legs. Three useful methods for determining prior knowledge and possible misconceptions are described below.

One of the simplest ways to determine prior knowledge is to observe and talk with students. As you teach and assist students, take the time to carefully observe their actions. Question students about their choices and reasons for actions. Record anecdotal notes in a notebook or portfolio for each student or develop a checklist to record the knowledge and skills you are observing. For example, imagine that you are teaching students about earthquakes. You might engage students in a hands–on investigation where they make clay models of faults. They might push and move the clay to investigate the effect on toy buildings as shifts occur along the moving fault lines. As a student moves the model, you can ask questions about the effect on the buildings, pose further questions about moving the clay in different ways, and determine whether the student understands how earthquakes occur. At a convenient moment, record notes about the individual's understandings that might affect future instruction.

Another example might include a checklist. Imagine the same lesson. You could move about your classroom with a checklist and class roster and record which students have particular understandings.

One technique commonly used by reading educators to develop a purpose for reading is called the **KWL Model** (Ogle, 1986). In this model, students are first asked to list what they know (K) about a particular topic before they read about it. Then, they identify what they want to know (W) about the topic. After reading, they analyze what they have learned (L). This technique is also effective in science classrooms to determine prior knowledge and guide instruction. Before teaching a particular concept, ask students to make three columns on a sheet of paper. Title the first column "Know," the second column "Want to Know," and the third column "Learned." Provide students time to list what they know about the topic and what they want to learn. Collect and analyze the list for prior understanding and possible misunderstandings. For example, you may have planned to teach about the nine planets in our Solar System, but you find that the students already know this. As a result, you can move forward with your instruction to another concept. On the other hand, you might find that most students were not aware of comets and wanted to know more about the possibility of one striking Earth. Now, you can plan your instruction around the students' interests. You may also have discovered that students have major misunderstandings about comets striking the Earth, and they do not understand that most comets that strike the Earth are burned up in the atmosphere before they ever reach the ground. This misconception can be addressed as well.

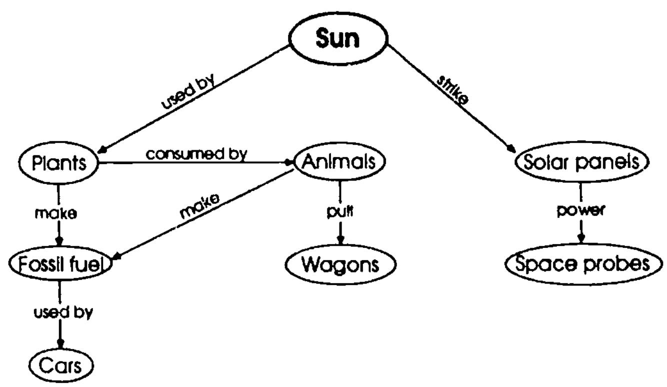
Finally, a third technique that we recommend to assess prior knowledge is **concept mapping**. Joseph Novak, a professor at Cornell, created the concept map as a tool to examine the changes in conceptual learning (Novak and Gowin, 1984). Concept maps are visual representations of the relationships the concepts have with one another. On a typical concept map, each concept word is enclosed by an oval, circle, or rectangle and the concepts are connected by lines and linking words. Together, the linking words and concepts form a network. The relationships between concepts are hierarchical — the more general concepts (super ordinate) are located toward the top of the hierarchy and the more specific concepts (subordinate) are located below in the degree of their generality. Cross–links are formed to show the interrelationships between the concepts included on the map. Connections between concepts can be linear, as well as horizontal. Meaningful learning occurs when a learner can connect or link new ideas or experiences with existing ones. Since the invention of the concept map, there has been an explosion of research on the topic. Concept mapping is now used in different ways in education. Educators use concept mapping as:

- a tool to assess students' prior knowledge
- as a method of exploring changes in meaningful frameworks
- as a thinking strategy to help students learn how to learn
- as a tool to improve conceptual learning by organizing incoming information
- as an assessment and evaluation technique
- as a teacher's aid in planning and instructional design.

It is the first use that we suggest here: using concept mapping to help determine students' prior knowledge.

Imagine that you want to teach about energy in our Earth Systems and you want to determine what students already know about energy. Students will need to have some instruction and practice on creating concept maps. However, after they know how to construct a concept map, the map can be used to help determine their prior knowledge on a topic. Pictured below is a sample map of a student's understanding of energy.

Energy Concept Map



Analyze the student's map above. What understandings are correct? Which are incorrect? What might you do as a teacher to facilitate the students' construction of knowledge about energy in the Earth's Systems? As you can see, this method helps determine what students know and assists with instructional planning. You can choose curriculum and instructional techniques that will facilitate conceptual change. In the next section, we will explore some techniques that are useful in facilitating conceptual change. For more information about concept mapping, see the article at the end of this section entitled "Mapping out Student's Abilities" reprinted from *Science Scope*.

Instructional Techniques that Facilitate Conceptual Change

From a Constructivist perspective, meaningful learning is about conceptual change. A variety of instructional strategies and techniques can help facilitate a student's construction of knowledge. The way that the teacher organizes the lesson and structures groups can make a big difference in the amount of quality time students get to explore their understandings, integrate new knowledge with prior understandings, or replace inadequate ideas that no longer fit with their current understandings. In this section, we will discuss two ideas—the *learning cycle* (an instructional technique that encourages exploration of ideas and integration of new knowledge with prior understandings) and *cooperative learning techniques* (which facilitates dialogue among students that encourages their exploration of their ideas).

Learning Cycle

One model for teaching that allows students to have the types of experiences called for in Constructivist theory is called the learning cycle. The learning cycle is a three–phase model for teaching students, developed by Robert Karplus, a professor of physics from the University of California at Berkeley who worked on the Science Curriculum Improvement Study (SCIS). It is based upon the belief that students need to explore a concept to be learned using real materials. The teacher can then help them "invent" the concept by relating the student's explorations with the knowledge that was to be learned from the exploration. Finally, the teacher can provide opportunities for the student to apply the concept to a new situation or further explore the concept.

Exploration Stage

In the exploration stage, students are allowed time to create knowledge and understanding of a concept. We have all had instances where, as students, we memorized something that had little meaning to us. Perhaps we memorized the words to a song in a school play or we may have memorized vocabulary words for a test. Did we really understand these? Students sometimes encounter concepts that are totally foreign to them in science. Unless they have the opportunity to explore the concept, develop understanding of it, put words to it, and expand upon it, it will have little real meaning.

Imagine a child about the age of six or seven who is learning about light and shadows. Given a flashlight, a mirror, various type of materials including transparent sheets of colored plastic, paper, aluminum foil, clear plastic, and a piece of wood, the child explores light and shadows. She shines the light onto the mirror and discovers that the light is reflected the opposite direction of where the light hit the mirror. She is confused about this and tries it several times. After several tries, she also discovers that the light not only bounces the opposite direction but at the same angle that it was placed toward the mirror. She looks at some writing in a mirror and notices that the writing looks backwards. She begins to make faces in the mirror, touch her left ear, then her right trying to figure out if she is backwards in the mirror! She discovers that light can pass through some objects and not others. When the flashlight is shined onto a solid (opaque) object, a shadow is formed. However, the transparent (totally clear objects that allow light to pass through and give a clear view of objects on the other side) and translucent (objects that let light through but things are not seen clearly on the other side) objects do not cast shadows.

Contrast this child exploring light and shadows with real objects to the child who is told by a teacher the definitions of reflection, shadows, opaque, translucent, and transparent. Does the child have any real

understanding of the concepts this way? No. This child has a set of rather meaningless words and no real understanding of what they mean. Unless children have had prior experiences with concepts that they can recall, they will not really understand the concept. Therefore, the central purpose of the exploration phase of the learning cycle is to allow the child to construct knowledge and assimilate new concepts into those learned from previous experiences.

Concept Invention

In the concept invention stage, the teacher discusses and provides formal instruction about the concept putting words to the understandings the students created. In the light and shadow lesson described above, the teacher who is teaching this lesson might gather the children in the class to discuss what they discovered. Students would share their findings about the light and mirrors. The teacher would introduce to students that these findings are showing that light can pass through transparent and translucent materials but not opaque materials. The teacher would also elaborate what is meant by "reflect" and "cast a shadow." Since the students have constructed their own understanding of these concepts, they will be able to use the scientific terminology without as much confusion. The words will most likely just reinforce some other word they may have been searching for. For example, a child may have been searching for a word to explain the light's ability to "bounce." The new word "reflect" can be accommodated into the child's mental structure.

Concept Application

We have just described a child who has assimilated and accommodated new ideas about light and shadows. These ideas are ready to be integrated with related concepts. In the concept application phase of the learning cycle, the teacher will expand upon the ideas learned, and students will be using their newly learned concepts and vocabulary. The teacher might engage students in another invest-igation where they explore whether the light will go through plastic, glass, aluminum, metal cookie sheets, and other objects. Students will expand their current understanding to see that light will reflect off of smooth, shiny surfaces (such as mirrors and glass) better than dull, scratched, or wrinkled sur-faces (such as aluminum foil or dull cookie sheets). The teacher might also show a video, have students watch an educational television program, or read a related text passage.

The learning cycle supports a Constructivist approach. Students construct their own understanding and meaning about concepts with real materials, and they are provided more than one experience with the concept. The learning cycle, however, should not be viewed as a hierarchical model for teaching. While we have described the learning cycle in three steps, it does not need to proceed in this order. The teacher might take three separate lessons to accomplish the cycle. The teacher may also flow in and out of the various phases several times in one lesson.

Cooperative Learning

Cooperative learning places students in groups where they work to solve a mutual problem or investigation. In doing so, students interact with others, discuss ideas, test ideas, and make compromises. They fit their experiences with that of

A cooperative learning group in the high school level BESS class at Worthington Kilbourne High School, Worthington, OH.

others. Because of this social interaction, cooperative learning is one of the most productive techniques in changing students' concepts because it involves interactions, the argument of ideas among students, individual thinking and writing, and the sharing of background and individual project research by students.

Using cooperative learning in a classroom means much more than placing students in a group. Students may not have all the skills that are necessary to cooperate in a group, so sometimes teachers encourage cooperation among students by structuring the lesson in some manner. The teacher needs to help students develop social skills, problem solving skills, and leadership skills that will enable them to work together in groups. Frequently this means that students are given particular "jobs" to insure that all members contribute equally to the group's desired goal. Jobs can vary widely but frequently include such jobs as manager, timekeeper, recorder, evaluator, encourager, reader, checker, and praiser. These jobs provide positive interdependence, that is a dependence upon others to complete the task. In addition, goals or objectives for completing the activity are clearly defined or explained to students. A large focus is placed on mastery by all students in the group and successful group cooperation.

Advantages of Cooperative Learning

Cooperative learning has generally been shown to be more effective than other forms of grouping students such as ability grouping, homogeneous grouping, and ability grouping within classes (Manning and Lucking, 1992; Slavin, 1992). Cooperative learning enables students to learn from each other—responsibility for learning is shifted from the teacher to students; it better assures that girls, minorities, or slower students (who may not view science as an endeavor for themselves) are not "lost in the cracks;" it helps develop students' abilities to work with others from diverse backgrounds; it helps girls overcome anxiety toward learning science; it enhances student self-esteem; it improves student attitudes toward learning; and it enhances learning (Hassard, 1990a; Hassard, 1990b; Manning and Lucking, 1992).

Manning and Lucking (1992) reported that two factors must be present in order for cooperative learning techniques to improve achievement. First, the technique must provide group goals whereby teams work interdependently to be successful. Second, there is individual accountability whereby each student must be accountable for learning and contributions to the whole group. Groups must also have appropriate social skills to be effective. Students must be allowed to get to know each other. They need to communicate effectively together, accept and support each other in the group situation, and be able to resolve conflicts when they arise. When these factors are in place, the self-esteem of students seems to improve as they see themselves as viable, contributing members of the class.

Skills for Cooperative Learning

There are a number of social skills that have been found necessary to facilitate the actions of students working in cooperative groups. Some of these include leadership skills, communication skills, listening skills, trust building, cooperation, and compromise. Why is it important for students to develop cooperative skills? First, scientists in the real world usually work on projects as a team. Group problem solving skills are essential in this type of situation. Second, these skills are deemed necessary for all citizens. In the late 1980s, the U.S. Department of Labor and the American Society for Training and Development identified the "basic skills" most employers indicated that they needed in employees. These desired skills included:

- the ability to learn how to learn and continually acquire new knowledge
- competence in reading, writing, and computation
- personal management such as goal setting and self motivation
- adaptability to engage in problem solving and creative thinking
- group effectiveness to work with a team of other people
- skills to influence others or leadership skills (Boyett and Conn, 1991).

These types of skills are developed in cooperative learning situations.

What are Some Different Types of Cooperative Learning?

Let us now explore the various types of cooperative learning arrangements. In some situations, students

are placed together to work on a single task, while in others they work independent of each other and later compile their findings to complete a task or problem. Many cooperative learning techniques exist with names such as teams–games–tournament, round robin, numbered heads together, pairs check, three–step–interview, think–pair–share, roundtable, and inside–out circle. However, the types of co-operative learning discussed here represent a few of the more commonly used methods in science education.

Student Teams Achievement Divisions

Student Teams Achievement Divisions (STAD) was developed by Robert Slavin, a professor at Johns Hopkins University. STAD has five different elements: class presentations, teams, quiz, individual improvement score, and team recognition. First, the teacher provides some type of class presentation such as a lecture, a textbook, a video, or other instructional strategy to teach a concept. Next, students are placed in teams where they work together to see that all members of their team understand the material the teacher presented. The goal of the team is to prepare everyone in the team for the third element, the quiz. After the team work is completed, students are administered a quiz. They take the quiz individually—not as a team. To motivate students to improve, each student is given a desired minimum score, and the team works to obtain the highest "team improvement score." Finally, teams are given some type of recognition (award, prize, verbal praise) for their improvement. Improvement is almost as important as the final score.

The advantages of this type of cooperative learning are that it provides frequent quizzes for teachers to assess student learning and the method is not as noisy as some other types of cooperative learning since the work is frequently completed as research where there are "correct answers" that are being sought. STAD is a relatively easy cooperative learning strategy to use. This type of cooperative learning model is very teacher directed, and it is an easy one to try first if you tend to be a traditional teacher or if you have not had much experience placing students into groups. It is an easy "first step" toward involving students in cooperative groups. You can learn more about this strategy by reading *Using Team Learning* by Robert Slavin (Baltimore: The Johns Hopkins Team Learning Project, 1986).

Jigsaw II

Jigsaw was developed by Eliot Aronson, and Jigsaw II was further promoted by Robert Slavin. The goal of this type of cooperative learning is to become an expert on one topic or concept and teach it to others. In turn, the student experts teach other classmates. There are three components to the Jigsaw II co-operative learning method: preparation of learning materials, teams and expert groups, and reports and quizzes. Students are divided into groups of four or five. In the first component, students are guided to what they should know, be able to do, or be like. Students are given some type of activity to complete (usually the whole class participates in the same initial activity). Then, they are divided into sub-groups and provided questions that they should be able to answer, to be an "expert." In the second component, "expert teams" are placed with "learning teams," and the experts teach the novices the desired concepts. Ideally, students are placed both on "expert" and "learning" teams to learn different aspects of a topic. In this way, they have the opportunity to be leaders in one situation and learners in the other. The goal of the "expert team" is to engage the "learners" in some type of activity to teach them the concept. They could use any type of instructional strategy ranging from hands–on investigations to group reports. In Jigsaw II, individuals are evaluated in much the same way as the STAD method; students take individual quizzes.

Let's describe an example of Jigsaw II. You might be teaching about cells. As a whole class, students might read the textbook section on cells. Then, you might place students into various teams to learn about "cells." One group might be instructed to learn all they can about cells from reference books. Another group might learn how to use a microscope to view cheek (animal) and onion (plant) cells. A third group might learn how to operate a software program on cells. A fifth group might watch a video on cells that compares and contrasts plant and animal cells. After each team becomes an "expert," they share their understandings with the class and engage classmates in the learning process. Individual students are evaluated on their individual understanding of cells as well as their group improvement. You can learn more about Jigsaw II by reading *The Jigsaw Classroom* by Eliot Aronson (Beverly Hills, CA: Sage Publications, 1979) or *Cooperative Learning*, 2nd ed. by R.E. Slavin (Washington, DC: National Education Association, 1987).

The PLESE program and several teacher education programs at Ohio State use a form of the Jigsaw. In the PLESE program we arranged teachers into expert groups that were heterogeneous; that is, teachers from different grade levels, but the same geographic area, were on the same team. Each teacher was also a member of a base group. In this grouping they were all teaching at the same grade level, either elementary, middle school, or high school. During the first stage of the cooperative learning program each expert group was given a topic to learn about some aspect of the Earth Systems such as global climate change. The high school teachers were able to help the elementary teachers with some of the terms and more complex topics as they did their reading and the discussion of the reading. When they were ready, a scientist who conducted research on the topic spent some time with the group discussing ideas with them. In the second stage of the process, they reassembled into their base groups. Now it was their turn to teach their topic to other members of their base group, each of whom had been in a different expert group. When the teachers had completed each of their presentations to their base group, a scientist again met with them to discuss different aspects of the topic. The third stage was to have each scientist make an hour or so presentation to the entire group on each of the topics. A similar approach is now being used in several teacher in–service courses at Ohio State.

Co–op Co–op

Co–op Co–op was developed by Spencer Kagen from the University of California at Riverside. The basic steps in this cooperative learning strategy are student–centered discussion, team selection, topic selection, team presentations, and evaluation. Co–op Co–op is very student directed. During student–centered discussions students discuss their interests and have a say in what they will learn. Students join teams based upon their interests, and they divide their topic of interest into smaller topics. Individuals research and learn about their subtopic, and they share what they have learned with members of their group. After a team of students has learned about their topic of interest, they prepare presentations for the rest of the class. They are encouraged to involve all members of their team in the presentation, and they are encouraged to actively involve the audience in some manner. For example, they might have their classmates participate in an improvisation play or a debate on a topic. The teacher can evaluate students formally (tests or quizzes) or informally (observations), but students are also encouraged to evaluate

Members of the two Arizona teams at the 1991 Western Center Workshop in Greeley, CO.

their own presentations. For example, students might be asked, "What did your group do well? What one skill does your group need to improve on? Did all members in the group participate?

The biggest advantage of Co–op Co–op is that it provides students a great amount of independence in choosing the topic and teams. Students learn leadership skills and must be responsible to make decisions for themselves. You can learn more about Co-op Co-op by reading *Cooperative Learning: Resources for Teachers* by Spencer Kagan (Riverside, CA: University of California, 1985).

Group Investigation

Shalomo Sharan developed this type of cooperative learning strategy. The strategy has five steps:

- topic selection
- cooperative planning
- implementation
- analysis and synthesis
- evaluation.

The first step, topic selection, is similar to Co–op Co–op whereby students are placed into groups to choose topics of interest and a strategy for learning the topic. Cooperative planning is accomplished by having the students and the teacher work together to develop procedures, activities, and goals that match the learning task. Students carry out the mutually developed "plan of action" in the implementation stage. In the "analysis and synthesis" step, students analyze what they learned and plan an interesting presentation for classmates. Finally the teacher and students work together to evaluate the team's presentation and achievement. Students can be evaluated individually or as a group, or perhaps both ways.

Let's explore how this strategy might be used in your classroom. Suppose your students indicate a strong interest in learning about rainforests and endangered animals. You could divide your class into groups of three or four students to explore this topic. Through cooperative planning, you and your class might decide to divide this topic into: types of animals that are endangered in the rainforest, causes of endangerment, and solutions to endangerment. You and your students might discuss ways to learn about these three topics by reading books, inviting a guest speaker, visiting the zoo, watching a video on rainforests, and completing a software program about rainforests. Cooperative groups would implement the mutually agreed upon plans to answer questions about endangered animals, causes, and solutions. In the next stage, groups would analyze and synthesize what they learned and present this information to classmates. Finally, you would work with your students to evaluate their learning. For example, you and your students might agree that you want to evaluate their classroom presentations. You can learn more about this strategy by reading *Cooperative Learning in the Classroom* by Shalomo Sharan, et. al. (Hillsdale, NJ: Lawrence Erlbaum Associates, 1984).

Planning for and Succeeding with Cooperative Learning

Setting up a cooperative learning lesson requires several steps that are different from other types of instruction.

1) Decide the goal of the lesson, and relate this to the students in some way, perhaps writing out the goal or demonstrating what they should accomplish at the end of the lesson.
2) Decide what type of cooperative learning strategy you are going to use and what size the groups will be. Select students for the groups. This can be done at random or by stratification which means that studer are purposely chosen by ability and students of various abilities are put in mixed groups.
3) Assign roles to each student in the group. Make sure each role or job is important and contributes in a significant way to solving the problem or reaching the goal.
4) Analyze what types of social skills will be needed by students in the situation. Teach students these social skills by modeling, discussing, or practicing them.
5) Review rules for getting along in a group such as "no put–downs" meaning accept the answers of others without criticizing them.
6) Determine how the group will be evaluated. Stress individual accountability for the objectives or concepts to be learned, but also emphasize team cooperation and successful interpersonal skills.

While cooperative learning should build social skills and cooperation among students, problems can arise. Sometimes students will try to let others do all the work. These "free riders" need to be encouraged to contribute to the group's task. Constant monitoring of group members' contributions to the goal will help you determine if you have any free riders. If you keep groups small, you will be able to notice any free riders more easily. In addition, assigning roles or jobs where every student's role is needed to complete the task helps solve this. The "dominator" is frequently a higher ability student who does not want to risk letting lesser ability students determine his/her fate. By requiring individual accountability and team recognition, you will help eliminate dominators because they will be able to demonstrate their own abilities and the team will only receive recognition if all students contribute. Finally, students will sometimes "gang up on the task" and reach a consensus that they will all devote the least amount of energy possible to completing the task. This results in a poor quality product or inadequate completion of the goal. You can help eliminate this behavior by demonstrating or modeling what you expect at the end of the lesson. For example, you might show a sample finished product. You can also set standards for reaching the goal such as each student reaching 80% on the test.

Assessment Strategies

As you have probably figured out, the traditional assessment techniques such as multiple choice or matching tests are not very accurate measures of conceptual change. Students can easily memorize answers to a test and not really understand what it is that they have regurgitated on the test. What techniques are useful to assess conceptual change?

First, concept mapping which we discussed under the section "Assessing Prior Knowledge" is also a useful technique for measuring conceptual change and understanding. Students can complete concept maps during the instructional phase to help demonstrate changes in understandings, and they can construct them to demonstrate understanding after a unit has been taught. Some educators assign points to different types of linkages in a concept map. For example, a student might receive one point for each level or hierarchy, one point for each relationship between two concepts, increasing points for branching from concepts (depending upon the level at which the branch occurs), and one point for each cross–link among concepts. A short, useful article about assigning points to evaluate concept maps can be found in the article entitled "Mapping Out Students' Abilities" found at the end of this section. An informative book for learning more about concept mapping is Novak and Gowin's (1984) book *Learning How to Learn*.

Performance Assessment

Knowledge and skills can also be measured with performance assessments. Performance assessment involves the use of manipulative materials. Students are given a set of directions, some manipulatives, and some questions to answer. They read the directions, complete some task requiring the use of knowledge and skills, and answer questions that will show the teacher that they have the appropriate understandings and skills. For example, a group of students might be given several soil samples and pH test kit. The directions tell the students that certain crops can only grow in a pH level ranging between 7 and 8. Students are told that they need to determine the pH of the soils. A color chart is provided to compare the resulting color and determine the pH level. The question that follows asks the student to indicate which soil samples would allow the crops to grow and survive. This question could be extended to measure problem solving if the students were asked what they could do to make the inappropriate soil samples viable for the plants. This performance assessment measures students' abilities to read directions, measure accurately, read a chart, and make a conclusion.

Performance tests are considered more authentic than written tests for measuring knowledge and skills because they provide a better match between instruction and assessment in a science classroom. Performance tests limit the opportunities for students to "guess" answers, and they provide a better indicator of what students know and can actually do, as opposed to what they cannot. Because performance tests are considered better measures of knowledge and skill development and are more appropriate in science classrooms, many states are adopting performance testing as part of their statewide assessments. In fact, large assessment companies, such as the Educational Testing Service (ETS), are also developing and adopting these types of tests.

Portfolios

Traditional forms of assessment supply the teacher with only snapshots of what students know, can do, and are like. Evaluation should be continuous rather than a one–shot effort. Educators have been using portfolios as a technique for matching assessment to instruction, assess students over time, and provide more than one form of assessment.

A portfolio can be a file folder, a box, or any other collection container for holding samples of student work over time. Some teachers use portfolios as "work in progress" in order to demonstrate how students have improved their work during the process of developing it. However, portfolios are really more than collection containers. The portfolio process, developed by science education professors Thomas Dana (from Penn State University), Deborah Tippins (from the University of Georgia), and Michael Kamen (from Auburn University) (1994), identifies **collection** as the first step in using portfolios. This step is where students and teachers collect evidence of student learning. The evidence can take many forms such as drawings, pieces of writing, photographs of student work, worksheets, and student products. Portfolios contain various samples of student work, or evidence, collected over the entire school year. **Reflection** and **selection** are the second and third steps in the portfolio process. The student, in collaboration with the teacher, selects pieces of work that represent what was accomplished after reflecting upon what important aspects were learned. During these two steps, students are provided some autonomy to help assess their own learning, because they are given a voice in the items that are selected for the portfolio. The last step in the portfolio process is **projection**. At this point, the student organizes the portfolio so that it is meaningful to others who might read or look at it. Portfolios enable educators to continuously assess students using a variety of evaluative formats.

What are the Advantages of Portfolio Assessment?

Portfolio assessment provides students, teachers, and parents with a continuous, multidimensional picture of students' growth and abilities. Because of the way portfolios are collected and evaluated, there are a number of advantages for students, teachers, and parents. Educators value portfolio assessment because it shifts responsibility for evaluating learning from solely the teacher to the student and the teacher. The process helps students become reflective thinkers, and this frequently encourages them to improve and achieve to their capabilities. Portfolio assessment is also praised because it focuses on individual students instead of requiring all students to complete the same tasks regardless of their interests and abilities. With portfolio assessment, students come to value learning and show pride in their work because they are not competing with others but rather are demonstrating their own achievements over time. An added benefit of the portfolio process is the supportive relationships that are formed between students, parents, and teacher. Because all work together to build the portfolio, a supportive environment is formed. Evaluation does not carry the stigma of being an anxiety–provoking experience, because the process promotes self–evaluation and goal setting rather than a final grade.

Teachers also tend to become reflective thinkers when they use portfolio assessment. They tend to think more about curriculum and as it relates to all students. They focus on what they can do to help individual students achieve knowledge, skills, and attitudes in science. Further, discussions between the teacher and students during the reflection and selection stage may provide insight to improving instruction that would have otherwise gone unnoticed.

Many people believe that portfolios accomplish several things for parents that other forms of assessment fail to do. Let's imagine, for example, that a student receives a "B–" on a science test covering the topic of predator and prey relationships. What does this tell the parent beyond the fact that the child answered 80% of the questions correctly on the test? Did the child learn more about predators and prey than the test measured? Is the child interested in food chains? Has the child developed scientific problem solving skills that will enable her to critically examine other animal relationships? These types of questions are usually not answered on traditional assessment measures. Portfolios can provide parents with a multidimensional approach to understanding their child's learning, and they can see the improvement that their son or daughter makes over time. Further, the parents are comparing their child with his or her own abilities; not those of others in the class. This helps parents focus on the child's successes rather than failures. In conclusion, portfolio assessment brings together students,

teachers, and parents in the learning process so that students can focus on setting goals and improving.

In this guide, we have provided you with additional information about assessment in the form of several articles you will find at the end of the section. In addition to the one on concept mapping already mentioned there are several others from the same issue of *Science Scope*. The first is entitled "Culturally Relevant Alternative Assessment." The authors have identified several types of assessments that they feel will provide a broader range of information from culturally diverse groups than do the traditional measures. These alternative assessment forms include concept mapping, group assessment, and journaling. We feel that this article will be of significant help to you as you change your assessment procedures. Another, "Portfolios: Questions for Design," will provide additional insight as to how to use portfolios in your assessment practices.

When attempting to use any of these alternative assessment techniques you are certain to run into the problem of scoring them. How can you provide a consistent measure of a student's performance that will be fair to all other students in your classes? In traditional evaluation techniques "objectivity" was insured by giving the same multiple choice, true–false, or matching questions to all students. Then it was simply a matter of scoring right and wrong answers (predetermined by you the teacher) and placing a numerical score at the top of the exam. This cannot be done with the types of assessment techniques now being recommended by science educators. One solution is to use Scoring Rubrics. These can be developed and applied to individual contributions in portfolios and to the portfolios overall. The article at the end of this section from *Science Scope* entitled "Scoring Rubrics: An Assessment Option," will help you to use this approach in assessing your students' achievement in science. Several examples of rubrics developed for use in Earth Systems classes are included at the end of this section.

TECHNOLOGY APPLICATIONS FOR EARTH SYSTEMS EDUCATION

ESE emphasizes relevant subject matter, decision–making, collaborative learning, current issues, and the need for many types of information to be brought together to bear on these topics. To operationalize the current goals of this type of curriculum restructure, emerging technologies are an important curricular addition to be sought. A beginning has been made toward integrating curricular areas, utilizing remote technologies and data sources in classrooms, and focusing on individuals' roles in the Earth Systems (Fortner, 1991). Scientists have begun to recognize the necessity for public education about their work, and projects are underway through government agencies and universities to make information available for teaching about complex Earth Systems problems.

There are numerous sources of environmental data available to educators, and this paper uses examples from a few. Earth Systems educators can seek out data they need from those who generate or store it, and use the data to help students take an Earth Systems approach to their science learning (Mayer, 1993).

Use of data is important in accomplishing most of the Earth Systems Understandings, but especially in 3, 4, and 5. We can, for example, demonstrate that studying the Earth involves more than one scientific method, e.g., we do not do *experiments* with the Earth (as in *the* scientific method), but study it using historical and descriptive data, and observations. We can also combine databases from very different sources to show how various factors interact, and we can use historical data to demonstrate how environmental conditions and components evolve over time.

CD–ROM sources. Most government agencies are now opting to store their volumes of Earth Systems Science data on CD–ROM, a medium Green (1991) calls "a tool for coping with the knowledge explosion." At the same time, Green laments the fact that teachers have been slow to recognize and utilize the capabilities of CD–ROM to keep abreast of research and critical thought in their own fields. This medium has become extremely cost–effective (as low as $20 to produce a data CD), and at the rate of one CD to hold the data from 1600 floppy disks, it is also economical in terms of storage space. Some exciting CD–ROMs, with data and some images, include:

- Temperature and Precipitation, U.S., 1890–1989 (National Climate Data Center)
- Toxic Release Inventory, 1991 (released annually, U.S. EPA)
- U.S. Census (U.S. Department of Commerce)
- Conterminous U.S. Landcover (U.S. Geological Survey and University of Nebraska, Lincoln)
- Joint Educational Initiative (JEI, designed for teaching, University of Maryland)

Data on these CDs are designed to be loaded into standard software spreadsheets for analysis and graphing, thus are accessible to many with a minimum of user training (Helgerson, 1989). As of 1994 most are designed for an MS–DOS platform.

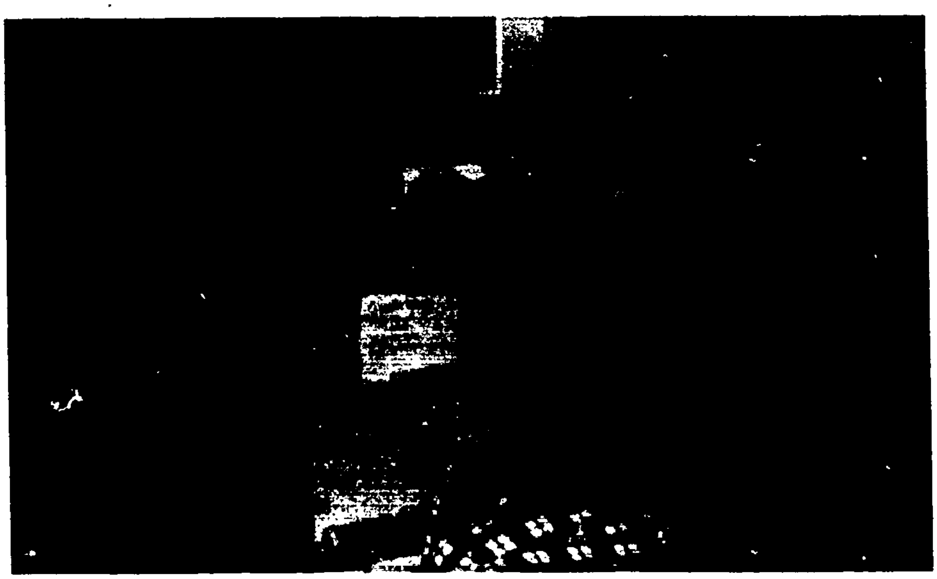
Encyclopedic CDs are also available on environmental topics, such as the Audubon Birds of America and Mammals of America set, and the World Data disk. Image disks with remotely sensed information and capabilities for image processing are also available for different parts of the U.S.

An excellent disk, designed for use in grades 9 and up, has been released by NASA and the Planetary Data System. Called "Welcome to the Planets," it contains image information on all of the planets and the sun obtained by Voyager and other probes. It is available from:

> Jet Propulsion Laboratory, Planetary Data Systems; PDS Operator 4800, Oak Grove Drive Mail Stop 525-389 Pasadena, CA 91109 or by internet at pds_operator@jplpls.jpl.nasa.gov.

Disk–based datasets. Certain organizations and agencies make datasets available on floppy disks. These tend to be downloads from magnetic tapes, and can be personalized by the producer to meet the user's needs, e.g., state data, topic specificity. Again, MS–DOS format is most common for those produced by government sources, but Macintosh versions are usually available for commercial packages. Examples include:

- Christmas Bird Count (by state, from U.S. Fish and Wildlife Service, Laurel, MD)



Earth Systems Education classes make heavy use of computers and other technology. This is a BESS class at Thomas Worthington High School, Worthington, OH.

- CO_2 studies, global change data (Carbon Dioxide Information Analysis Center)
- Water data, by state or watershed (U.S. Geological Survey)
- *Global Recall* (world data HyperCard stack and more, from the World Game Institute)
- Ice formation on the Great Lakes (Great Lakes Environmental Research Laboratory)

Hard copy datasets can also be put into electronic format by students or teachers, and the material can be analyzed for very specific applications. Examples of sources of these data include:

- Published datasets in scientific journal articles (data have been preselected)
- *World Resources 1994–95* (tables in the back are analyzed in early chapters)
- Government technical reports (a fairly elusive source)
- Almanacs and resource reviews

There are usually no published guidelines for teachers to use data such as these, so applications must be created within course contexts. The global change capstone course in Ohio State's Geography Department, for instance, uses a special grouping of hard copy data in an "Environmental Insult" laboratory. From a small database of several widely differing countries, the magnitude of each country's regional and global insult to the environment is calculated. After scatter–plotting their calculations, students can group the countries according to their known developmental status. Calculating the insults with different relationships among the data will yield different groupings.

On–line Databases. With a modem and phone line students can be connected to numerous datasets available through electronic networks. Such data can be accessed in forms that are updated constantly, and in some cases can be added to by the users. Specialized networks that deal with only data exchange are available, mostly from government sources; for other networks data access is only one of many services offered. Some examples are:

- Accuweather and other weather satellite data capture networks
- USGS Earthquake Line, with daily reports of locations of tremors
- National Geographic KidsNet, sharing regional data and environmental measurements such as acid rain
- RTKnet (Right to Know), a private service combining the EPA's Toxic Release Inventory and other environmental databases with the data of the U.S. Census

An *ERIC Digest* describes the state of K-12 computer networking and its potential in all disciplines for the improvement of education through on–line communication. It is included at the end of this section.

Thus it is evident from even a brief overview of media that Earth Systems Science data are available for classroom uses. Projects underway at Ohio State University, North Carolina State University, the Office of Sea Grant, Aspen Global Change Institute, the Geographic Alliance, and other organizations and agencies promise to offer teachers more and more opportunities for use of such data in classroom science teaching.

You must learn to cruise the Information Highway. Your students will. If you are uncomfortable trying to learn the intricacies of travel by *ftps* or *gophers*, perhaps you can find a student to help. You will be greatly rewarded by finding a treasure trove of images, activities, information, and other resources. The CD–ROM from the Jet Propulsion Lab mentioned above, for example, can be downloaded into a computer. Of course, you would need a rather large capacity hard drive to accommodate all of the data on a CD–ROM, so in this case you are better off ordering it directly from JPL and waiting the week or two it will take to be delivered. But get into *Netscape* or *Mosaic*. These are programs available on the internet that can be downloaded into your computer. They will assist you in finding and using really valuable information. The Weather Underground group at the University of Michigan has developed an interactive program which allows access to weather and environmental images and animations. Blue–Skies can be used by anyone at the current time. However you do need some special

software called Serial Line Internet Protocol or else Point–to–Point Protocol to connect to the Blue–Skies server. You can obtain information and help from their "Home Page" (http://cirrus.sprl.umich.edu/) or you can send a letter to: The Weather Underground, Department of Atmospheric, Oceanic, and Space Sciences, University of Michigan, Ann Arbor, MI 48109-2143.

Global Education in Science

With changes in the international situation resulting from the end of the Cold War, we seem to be entering a truly global era. Social studies teachers have developed a program called Global Education which emphasizes the variety of cultures and common interests that exist around the world. They have developed instructional materials and teacher enhancement programs to acquaint social studies teachers and their students with these global issues. Science is truly a global discipline. It invites participants from any culture to investigate the world in which we live. Therefore there needs to be an element of global education in science courses. The article by Mayer entitled "Teaching from a global point of view" is included at the end of the section to provide Earth Systems teachers with ideas as to how they can provide a more global view in the courses that they teach.

Conclusion

In this section we have tried to provide a series of hints and ideas as to how you can provide a classroom climate that is supportive of an Earth Systems approach to science teaching. You will need to use constructivist methods of teaching such as the learning cycle and cooperative learning. You will need to use assessment procedures that give you a better idea of depth at which your students have learned the science concepts you have taught them. Thus we have provided some information on alternative assessment methods. We feel technology and the use of databases will become increasingly important in science classes especially at the high school level. That portion of the section was contributed by Rosanne Fortner who has been deeply involved in developing database activities and teacher enhancement programs to assist them in using databases in instruction. Finally we would like you to consider a global approach to teaching your Earth Systems courses. We have provided some articles at the end of the section which are short and rapidly read, yet have useful ideas and insights that will help you to expand upon the necessarily limited information provided in this narrative. In addition, suggestions have been included on additional resources in constructivist learning, alternative assessment, and technology.

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The 1992 PLESE Western Center participants with Ray Tschillard and Bill Hoyt, Directors.

Student Name ____________________ Class ____________ Date ______
Total Score ____________ Grade ______________

Scoring Rubric — Individual Student Reports and Presentations

	Level 1 Minimal Achievement	**Level 2** Rudimentary Achievement	**Level 3** Commendable Achievement	**Level 4** Superior Achievement	E: Ac
Scientific Thought (content) Possible 40 points	Lacks an understanding of the topic. Very little research, if any; incorrect use of scientific terms. 0 5 10 15 20	Poor understanding of topic; inadequate research; little use of scientific terms. 21 22 23 24 25	Acceptable understanding of ttopic; adequate research evident; sources cited; adequate use of scientific terms. 26 27 28 29 30	Good understanding of topic; topic well researched; a variety of sources used and cited; good use of scientific vocabulary and terminology. 31 32 33 34 35	Comple ing of to sively re of prima seconda used an and effe scientifi and terr 36 37
Oral Presentation Possible 30 points	Poor presentation; does not communicate science content to peer group. 0 5 10 15	Presentation lacks clarity and organization; ineffective in communicating science content to peer group. 16 17 18	Presentation acceptable; only modestly effective in communicating science content to peer group. 19 20 21 22	Well–organized, interesting, confident presentation supported by multisensory aids; scientific content communicated to peer group. 23 24 25 26	Clear, c ing pres support multise scientifi effectiv cated to 27 2
Exhibit or Display Possible 30 points	Exhibit layout lacks organization and is difficult to understand; poor and ineffective use of materials. 0 5 10 15	Organization of layout could be improved; materials could have been chosen better. 16 17 18	Acceptable layout of exhibit; materials used appropriately. 19 20 21 22	Layout logical, concise and can be followed easily; materials used in exhibit appropriate and effective. 23 24 25 26	Exhibit wxplan success rates a approa of mate 27 2

SAMPLE RUBRIC

This rubic was developed by an Earth Systems teacher for use in evaluating individual student research projects.

RESEARCH TIME UTILIZATION	The student needed continual reminders to get back to work. Work may be inappropriate to the project.	The student was usually on task, but needed an occasional reminder to get back to work. All work is appropriate.	The student was always on task and did not need reminders to get back to work.
PARTICIPATION IN PROJECT	The student does not add an equitable amount of work to the project and does not meet all requirements for the length of presentation.	The student adds an equitable amount of work to the project, but may not meet all requirements for the length of the presentation.	The student adds an equitable amount of work to the project and meets all requirements for the length of the project.
ACCURACY OF INFORMATION DURING PRESENTATION	The student's information was lacking in content and was not factually correct in many places. Information may not be pertinent to the presentation.	The student's information is for the most part factually correct. Information may not be pertinent to the presentation.	The student's information is factually correct and pertinent to the presentation.
CLARITY OF PRESENTATION	The student's work is not well planned. The student was confused by much of the information presented. The student was not clear in explaining topics.	The stuc' ' work is well plannec .ere seemed to be some)nfusion or misinterpretation of information.	The student's work is well planned and clearly explained. The student showed a clear command of the information presented.
VISUAL AID WORKSHEET, OR SIMPLE DEMONSTRATION	The device used by the student was not used at a timely place in the presentation, had little bearing on the presentation, or was absent from the presentation	The device used by the student was appropriate for the presentation. It may have been used in a more appropriate manner. The design of the device may not have maximized the learning.	The use of the device was timely and appropriate. The design of the device was constructed to maximize learning.

South–Western City Schools
Park Street Middle School - Team 6
Portfolio Assessment
School Year 1993 - 1994

Learner:______________________________ Date:________

5 = Excellent Effort 4 = Good Effort 3 = Average Effort 2 = Below Average Effort 1 = Poor Effort 0 = No Effort
NA = Not Applicable

Portfolio Assessment	Evidence	Code
Demonstrates ability to make observations:		
Shows evidence of good measurement skills:		
Shows evidence of making hypothesis and predictions:		
Shows evidence that the Earth is unique, a place of great beauty:		
Shows evidence that human activities are seriously impacting Earth:		
Shows evidence that using science and technology helps us understand the Earth:		
Shows evidence that the Earth is composed of interacting subsystems:		
Shows evidence that the Earth and its subsystems are continually evolving or changing:		
Shows evidence that the Earth is part of a solar system within the vast and ancient universe:		
Shows evidence that there are many careers that involve the study of the Earth, its subsystems, and processes:		
Project:		
Notebook:		

GROUP MEMBER EVALUATION FORM

Student Name ______________________________ Group Table ______________

For your group to do the best possible work, all members must contribute a fair share to the group effort. Members who do not contribute can bring down the performance of the whole group. To help your group make sure that responsibilities and tasks are shared fairly, use this form to evaluate the contributions of your teammates. Grade each group member for each class period of the investigation. Use the following scale to assign grades. (Note: 4 is the highest score each day, 0 is the lowest).

Grade	Criteria
4	→ participated to the best of his or her ability → was helpful and cooperative → stayed on task → did an excellent job on the required research or homework
3	→ participated actively, but could have done more → was cooperative → was usually on task → did a good job on the required research or homework
2	→ participated some, should have done more → was cooperative some of the time → was off task at times → did a fair job on the required research or homework
1	→ participated only a small amount → was usually cooperative → was off task some of the time → did a poor job on the required research or homework, or did nothing
0	→ did not participate → was off task most of the time → showed behavior that disturbed the rest of the group or class

Student's Name	Day 1	Day 2	Day 3	Day 4	Day 5	Total Points

ERIC CSMEE Digest

Clearinghouse for Science, Mathematics, and Environmental Education EDO-SE-93-1 March 1993

Computer Networks for Science Teachers

Kimberly S. Roempler & Charles R. Warren

Computers and the technologies associated with them are major forces in the virtual shrinking of the globe. Through computer networks, students and teachers across the United States and around the world are interacting to share experiences and to investigate local problems in a global context. Formerly reserved for use by scientists, researchers, and computer buffs, computer networks now have capabilities that make them extremely useful to science teachers and their classes.

A network links computers via standard telephone service. Electronic mail (e-mail), data, software, and other messages can be sent and stored to be read sometime later by the receiver. With a modem and a computer, one can "meet" science educators with common interests in almost any area of the country or the world, 24 hours a day. Educators can easily be on the cutting edge of the use of instructional technology through the use of computer networks.

This digest is designed to provide educators some basic background on computer communications and to provide a few examples of computer networks that are easily available to them and their students.

The Power of Communication

Telecommunications can add vitality and excitement to the classroom. Students and educators see subjects come to life as they study topics such as tropical timber resources, environmental crises, or the AIDS pandemic. Through telecommunications, classes can be in contact with individuals and organizations who address these issues on a day-to-day basis.

Science classes can also communicate directly with other science classes around the world to conduct research or explore and share ideas. This kind of across-the-globe networking can be an exciting project for students of all ages. In one recent effort, for example, elementary school students from across the United States measured daily precipitation and the acidity of collected samples of rainwater. This information was shared on a computer network with classes from many parts of the country, and a daily acid rain map was created. Other activities have included on-line science fairs and on-line surveys. Networks have allowed the creation of an exciting "global classroom" both in its content focus and its participation.

The Advantages of Electronic Mail

A common complaint of science teachers is the feeling of isolation from other professionals with similar interests. Computer networks allow teachers to "reach out and touch someone." Teachers can share ideas and activities through the use of electronic bulletin boards. Networks can also serve as resource retrieval databases. Data retrieved from computer networks can be analyzed by students. Computer networking improves communication and data exchange by allowing participation in ongoing computer conferences as well as private e-mail. Increased productivity, creativity, and professional activity are some of the results of using computer networks.

Using a computer network can save communication time and money. One has the freedom and flexibility to use the service in a timely manner—whether it's six in the morning or midnight. Sending correspondence via e-mail can be more productive than trying to get someone over the phone, because mail is held for retrieval until the user logs on.

Dealing With Networking Charges

The costs of networks vary. Startup expenses can include the costs of a computer, modem, software, and user fees. For a long distance network, on-line time can be quite expensive. There are, however, several ways to cut some of the costs. Because the networks can be used at any time, using the service in the evening and on weekends can cut costs considerably. To decrease the time needed on the phone, some networks allow messages to be composed in advance, off-line, and then transmitted electronically. This is called uploading. Uploading results in less time on-line and therefore lower phone charges.

Different terminal systems can also affect costs. Some computer networks use "smart terminal" systems while others use "dumb terminal" systems. A "smart terminal" system, where the microcomputer is pre-programmed to run the network computer, runs quickly and efficiently and results in lower phone line charges. "Dumb terminal" systems require all work to be done on-line and are therefore more costly.

Many teachers do not have time to interact frequently with computer networks while at school. Fortunately, most computer networks are available on a 24-hour basis making this type of communication exceptionally flexible.

Networks Available to Science Teachers

Science Line, EcoNet, PSINets, INTERNET/BITNET, and ERIC OnLine systems are examples of computer networks that have much to offer science educators.

Science Line, a National Science Teacher Association (NSTA) sponsored electronic bulletin board, allows a user to scan and download a variety of science and general interest programs, including public domain and shareware software, the latest information on summer programs and NSTA projects, official information files from government agencies and organizations, text on computer techniques and scientific papers on topics like cold fusion, teacher aids such as gradebook programs, and interesting classroom demonstrations.

EcoNet is an international computer network related to the environment and education. EcoNet serves environmental educators as part of its broad mission to provide information services to the international environmental community. As a central program of the Institute for Global Communications (IGC), EcoNet allows users to send messages to

another continent, gather the latest information on a wide variety of environmental topics, interact with other members of the environmental community around the world, look for a job in the environmental field, or find a foundation that might fund a project. Both *Science Line* and EcoNet require on-line time because they are "dumb terminal" systems.

PSINets, initiated in 1985, are People Sharing Information Networks. Different PSINets have been established in various states (e.g., Iowa, Georgia, and Ohio) with the cooperation of IBM and the Council of State Science Supervisors (CSSS). Typical conferences currently available on these networks include: (1) curriculum materials, (2) announcements, (3) forums, (3) surveys, (4) projects, (5) phonebooks, and (6) activities for students.

At the state level, PSINets have found great success. In 1991, for example, every school district in Ohio was offered inservice training on the use of PSINet networks, and more than half received the necessary software to use OHNet (the Ohio PSINet). A toll free number was established by the Science Education Council of Ohio and the Ohio Department of Education. This number has allowed science teachers and administrators to access the network without telephone charges. Through OHNet, Ohio teachers are informed about local, state, and national science education resources, trends, and curriculum developments.

PSINets are networked to national PSINets such as the National STS network, the Council of State Science Supervisors PSINet, and PSINets in other states. Communication between sites across the country and around the world is made possible through this network of networks. Many states are operating PSINets at this time.

PSINets are examples of "smart terminal" systems. PSINet uses a unique IBM software package that allows a user to run the network server computer from one's own microcomputer with greatly decreased on-line time. Typical daily phone calls between the user and the server last less than two minutes. Plans for the growth of PSINet involve a software version for Macintosh computers and a link to INTERNET.

INTERNET and BITNET are academic computing networks that are becoming available to teachers in some areas. The computer network in the state of Texas links hundreds of teachers through an INTERNET system. Commonly accessed through local universities, BITNET/INTERNET systems can be interfaced through the use of several different software packages. These systems have many international connections and can link a user with a variety of resources such as databases, library holdings, and other networks.

SUNINFO, a campus information system at Syracuse University that uses the SPIRES/*PRISM* interface, allows INTERNET users to access the last five years of the ERIC Database. A full-text file of over 850 ERIC digests is also available to INTERNET users through the Extended Bulletin Board of the Office for Information Technology, University of North Carolina at Chapel Hill. For more information about these and other ERIC OnLine systems, contact ACCESS ERIC: 1-800-LET-ERIC.

Getting Involved

The computer networks mentioned in this digest are only the tip of the iceberg. There are hundreds of local, regional, national, and international computer networks. Most computer networks can set up an account and a password over the telephone. Research and history involving networks tell us that successful networks share three things: (1) involved users on the system; (2) active paper mail support; and (3) occasional face-to-face meetings between users. Networking will expand educators' horizons on both the personal and professional level.

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Science Line
National Science Teachers Association
1742 Connecticut Ave. NW
Washington, DC 20009
(202) 328-5853

EcoNet
Institute for Global Communications
3228 Sacramento Street
San Francisco, California 94115
(415) 923-0900
(415) 923-1665 (FAX)
Telex: 154205417

ERIC Clearinghouse on Information Resources
Syracuse University
Syracuse, New York 13244-2340
(315) 443-3640
(315) 443-5448
Internet: ERIC@SUVM.ACS.SYR.EDU

PSINet
Contact your state science or mathematics consultant at your respective department of education or:
Jack Gerlovich
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OERI This digest was funded by the Office of Educational Research and Improvement, U.S. Department of Education under contract no. RI-88062006. Opinions expressed in this digest do not necessarily reflect the positions or policies of OERI or the Department of Education.

ERIC Educational Resources Information Center. The nationwide information system initiated in 1966 by the U.S. Department of Education. ERIC is the largest and most frequently used education-related database in the world.

SE 053 449

Deborah Tippins and
Nancy Fichtman Dana

Culturally Relevant Alternative Assessment

Because experience is embedded within culture, learning should be considered in a cultural context. Similarly, assessment involves the representation of knowledge and a judgment concerning the viability of that knowledge. Thus, assessment should be context dependent; reflect the nature of the subject matter; and address the unique cultural aspects of class, school, and community among culturally diverse populations.

Why culturally relevant assessment?

Broad movements for reform and change in science and mathematics—such as Project 2061; the Scope, Sequence, and Coordination Project; and Curriculum, Evaluation, and Professional Teaching Standards for School Mathematics—must be influenced by the development of more culturally responsive means of assessing student learning in science and mathematics. The need for culturally relevant assessment reflects the diversity of our society, where students of color are expected to comprise 33 percent of public school enrollment by the year 2000.

Assessment in the next decade must challenge old assumptions. The inadequacy of standardized testing as a sole measure of what students know has been compounded because these tests too often portray an inaccurate picture of minority students' capabilities. As the Quality of Education for Minorities Report (1990) points out, test scores alone are poor measures of student potential.[1] Such measures fail to consider interpersonal skills, language abilities, and related talents that students will need in the real world. Beliefs and knowledge about culturally diverse groups may also have served to limit perspectives, ultimately contributing to reduced opportunities in fields such as science. Culturally relevant alternative assessment is needed to improve educational options for students from diverse backgrounds.

A critical factor in culturally relevant assessment is the realization that alternative assessment in multicultural populations will be different from other forms of assessment. Because all students bring with them a unique set of experiences, the developers of alternative forms of assessment must take these experiences into consideration. This is critical if one views improving learning as the primary purpose of assessment.

Assessment for all

The following alternative assessment strategies enable students in science to "show what they know" regardless of their cultural background. Furthermore, many of these strategies celebrate cultural diversity, for it is through alternative assessment strategies that both students and teachers from diverse backgrounds may learn to appreciate the uniqueness as well as the universality of their particular culture.

Concept mapping

Concept maps are constructed by selecting and writing major concepts and ideas in a circle or oval, and then joining related concepts with lines and connecting verbs that explain the relationships between concepts. Concept maps become tools for negotiating meanings between students when a culturally diverse group of two or three students must share, discuss, negotiate, and agree upon meanings in order to create a concept map. Novak and Gowin suggest that bilingual students may present foreign words that label the same events or objects.[2] By doing this, science students learn that language does not make a concept, but rather language serves as

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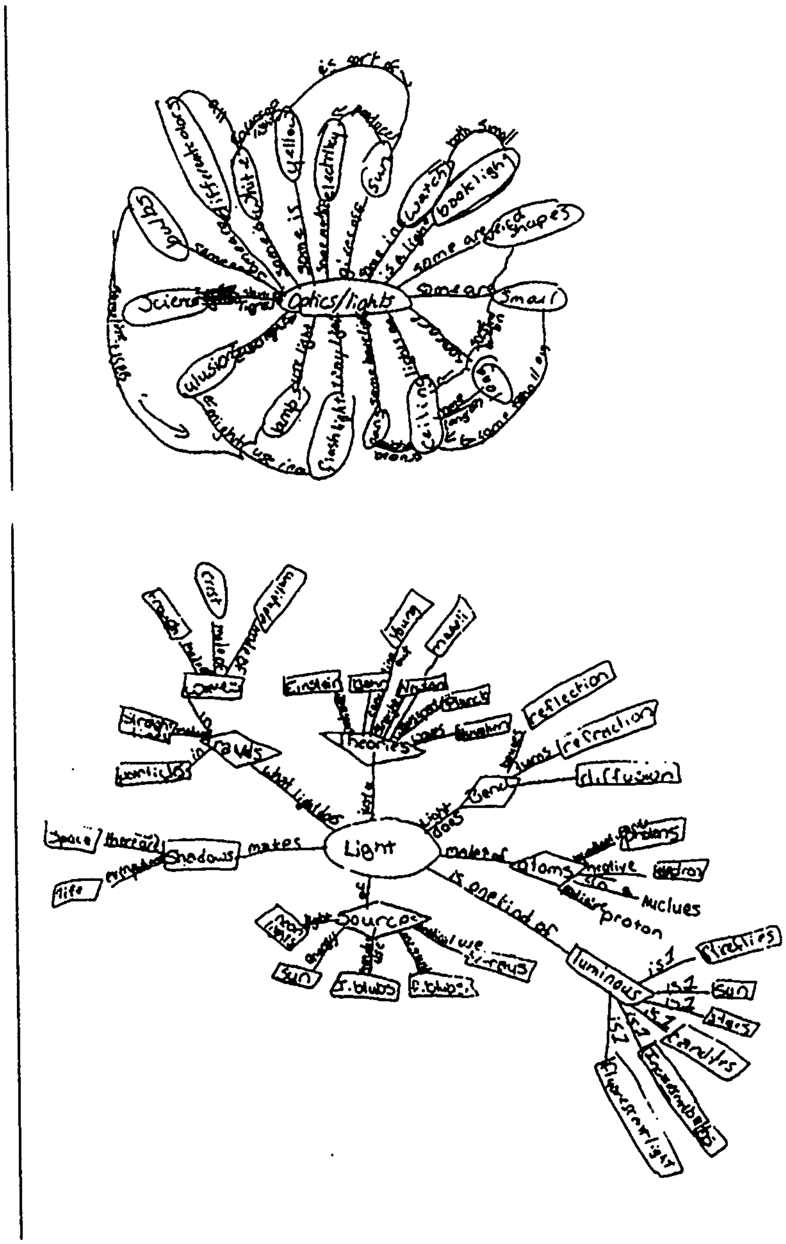
the label for a concept. A pre and post concept map (See Figure 1) can be one culturally relevant tool used to assess student learning in science.

Cooperative learning and group assessment

The common theme in all cooperative-learning, group-assessment strategies is that the grade earned fosters positive interdependence—how students work with one another is a prime factor in the grade received. Thus, students engage in dialogue to construct and negotiate a shared meaning of their science learning, and group members benefit by helping one another. In the process, students come to understand and appreciate cultural differences. Research on cooperative learning involving different ethnic groups, handicapped and nonhandicapped students, and male and female middle school students indicates that "cooperative learning experiences, compared to competitive and individualistic ones, promote more positive attitudes toward members of a different ethnic group or sex and handicapped peers."[3] Thus, cooperative learning not only offers an alternative to traditional, individualized, competitive assessment practices; but promotes attitudinal changes between culturally diverse students as well.

Figure 1. Student Pre and Post Concept Map



Journaling

Journaling becomes an alternative approach to traditional science testing when it is used for assessment purposes. Journal writing encourages students to connect science to experiences in their own lives and it helps students find connections between experience and theory.[4] Journaling is also culturally relevant in that it is a personal process in which grammar and punctuation are unimportant, thus not placing ethnic students at a disadvantage due to linguistic differences in grammar, lexicon, and style of dialect. When students keep journals of their science learning, they articulate their thought processes. When students share journal entries with one another, they may come to appreciate linguistic differences and the expressive power of language.

For assessment purposes, a unit of study may begin with students writing an entry on what they know about a particular scientific concept. Throughout the unit, students continue to write entries regarding their learning and how it relates to their life experiences.

Dialogue journals and *roving journals* are two additional ways of using journals for assessment. They enable students to communicate with each other about their learning. Dialogue journals place students in two-way conversations,

Figure 2.

Date : Tuesday, September 3
Topic : Reflection on the first week's activity

I learned that Mr. Hook is a cool dude who assigns homework most of the time. Also not to sterotype the color or sex of a scientist

It has changed my view of the world by, All scientist are not white, and all are not male

What I will do with this information is when I draw scientist I will draw minorities, and of the oppisite sex. And spread the news to my friends.

Good

My mom is a chemist and she is Indian.

So she. It's good to know.

focusing on the process of making sense in learning science. With dialogue journals, students make sense of their individual involvement with key science concepts by "talking with a friend." Students exchange journals on a regular basis, providing feedback and comments that facilitate further reflection. Roving journals are a powerful vehicle for helping students search for connections between their prior knowledge and new information. Roving journals focus on a particular science concept or activity. The journal is passed around the classroom and each student writes about the theories he or she used to make sense of the concept. As different students write explanations, students benefit from the ideas of the students before them.

When using any type of journals, it is important for students to consider how their thinking develops and reflect upon learning experiences both historically and in a cultural context. When students are allowed to communicate through journals, they become personally involved in learning and ultimately become participants in the assessment process. Figure 2 illustrates how teachers can use dialogue journals to assess student understanding of science concepts.

Oral interviews

Oral interviews provide an alternative assessment strategy that encourages students' self-confidence in posing questions in their own language in the context of their own experience. Teachers and students alike need opportunities to share their "stories," for in doing so, they demonstrate their individual questions and perspectives, which are essential in weaving the threads necessary to make sense of experience. Some topics around which oral interviews might initially be structured include job interviews and related accomplishments, interviews concerning controversial issues (including both biased and nonbiased accounts), and science-related oral histories.

Portfolios

The portfolio should provide a developmental record of growth in conceptual understanding for both teachers and students. The use of portfolios in assessment reflects a fundamental change from traditional assessment practices in many ways: The development of portfolios allows teachers and students to work and learn together; provides opportunities for reflection and self-assessment; helps redefine traditional student and teacher roles in relation to the science curriculum; emphasizes the culture in which teaching and learning occurs; and empowers both students and teachers with respect to science learning.

Many of the assessment tools already mentioned can be introduced into the assessment portfolio: concept maps, journals, oral interviews, and cooperative group assessment. Using multiple sources to profile student growth can help insure equitable treatment of culturally diverse students. But portfolios cannot be suddenly introduced into a science classroom without corresponding changes in the way we think about knowledge construction in relation to science teaching and learning. This calls for radically transformed science classrooms and new roles for teachers and learners.

Conclusions

In *Multiethnic Education*, Banks calls for the development and use of novel assessment practices that reflect various ethnic cultures.[5] It is important, however, to heed Banks' warning that alternative assessment strategies will do little good unless educators implement curricular and instructional practices that are also multiethnic and multiracial. The task of "fitting the school to the student" is difficult when schools define learning as "mastery" of isolated bits of data and marginalize conceptual knowledge and the related processes of problem solving and problem detecting. The strategies we present here cannot substitute for a multiethnic and multiracial science curriculum and learning environment. Any discussion of assessment must be linked to understanding what we teach, how we teach, and why we teach. A multiethnic and multiracial science curriculum and learning environment, as well as culturally relevant assessment strategies, can enable teachers to better prepare their students for the multicultural society in which we live ■

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ELENA MALDONADO VARGAS
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Mapping Out Students' Abilities

Concept maps, diagrams that indicate the relationships between concepts, reflect the conceptual organization of information. A well-thought-out system of concept maps can be used to formulate questions for such traditional evaluation systems as exams. On the other hand, if students are asked to draw their own concept maps, the maps can serve as an assessment tool for evaluating students' abilities to differentiate and structure the key concepts of class material.[1]

In this article, we will present a modified form of the concept-map scheme created by Novak that provides a consistent syntax and grading system for concept maps.[2]

The syntax and the grading

Figure 1 represents the structural syntax of a concept map. Within the concept map, a point or period represents a concept, and the lines connecting the points represent the relationships between the concepts. Each relationship drawn must be described by a proposition or relationship description. The map is drawn as a tree with the hierarchical levels numbered in descending order. The grading scheme awards points as follows:

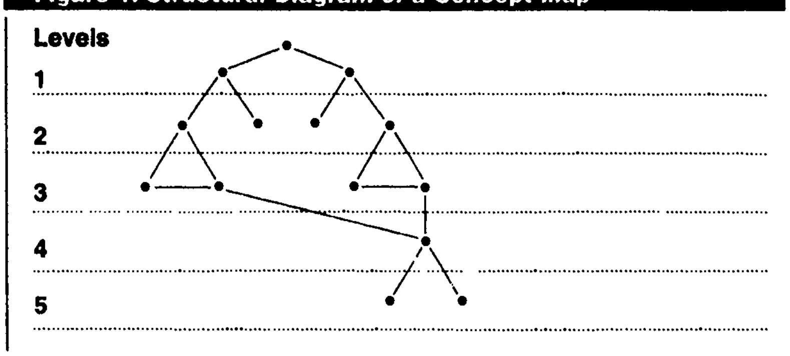
1. Hierarchy—One point for the number of levels that are correct. (Figure 1 portrays a five-level concept map and would therefore receive 5 points for its hierarchical complexity.)

2. Relationships—A student receives one point for each relationship drawn between two concepts and described by an explicitly and correctly described proposition. (Figure 1 contains 16 relationships between concepts, yielding 16 points.)

3. Branching—A branch is a relationship established between one concept and two or more concepts at the next hierarchical level. The number of points awarded for branching depends upon the level at which it occurs. Award only one point for the first level of branching, but give 3 points for any branching that occurs at subsequent levels. Figure 1 should receive a total of 16 points for branching: one point for the initial branch at level 1, 6 points for the branching that occurs at level 2 (two branches), six points for the branching at level 3 (two branches), and 3 points for the one branching at level 5. (No branching occurs at level 4.)

4. Cross-links—A cross-link connects relationships and reflects integration or parallelism between two relationships. Award one point for each cross-link. Figure 1 contains three cross-links (two cross-links on level 3 and one on level 4), yielding 3 points.

Figure 1. Structural Diagram of a Concept Map



An example

For a more concrete example, consider the concept map shown in Figure 2. When evaluating a concept map, first divide it into levels as shown in the diagram. Then proceed through the evaluation as follows:

1. Hierarchical levels—4 points. Figure 2 has four levels; award one point for each level.

2. Relationships—17 points. Look for relationships between concepts that are established by a correct proposition, for example, "Matter is Heterogeneous" or "Solution is a Mixture" and score one point for each. Figure 2 has 17 correctly established relationships.

3. Branching—10 points. Figure 2 has four branches. At level 1, "Matter" branches to two concepts, and receives one point because it occurs at the first level. At level 2, "Heterogeneous" does not branch but "Homogeneous" branches once, yielding 3 points. At level 3, "Solution" and "Substance" both branch, so award 6 points for branching at this level. There are no branches at level 4.

4. Cross-links—4 points. Figure 2 has four cross-links—"Solution is a Mixture"; "Solute in Solvent"; "Water is a Solvent"; and "Solvent example H_2O." Remember that every cross-link establishes a connection between concepts.

For practice, evaluate the concept map about photosynthesis that is depicted in Figure 3. Use the key presented at the bottom of the figure to check your results.

An assessment tool

The classroom teacher needs to use different instruments and techniques to evaluate students. Concept maps can be useful for determining students' cognitive structuring of information and assessing how thorough an understanding they have of a topic. Add concept maps as an evaluation tool to your assessment repertoire ■

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Figure 2. Concept Map on Matter

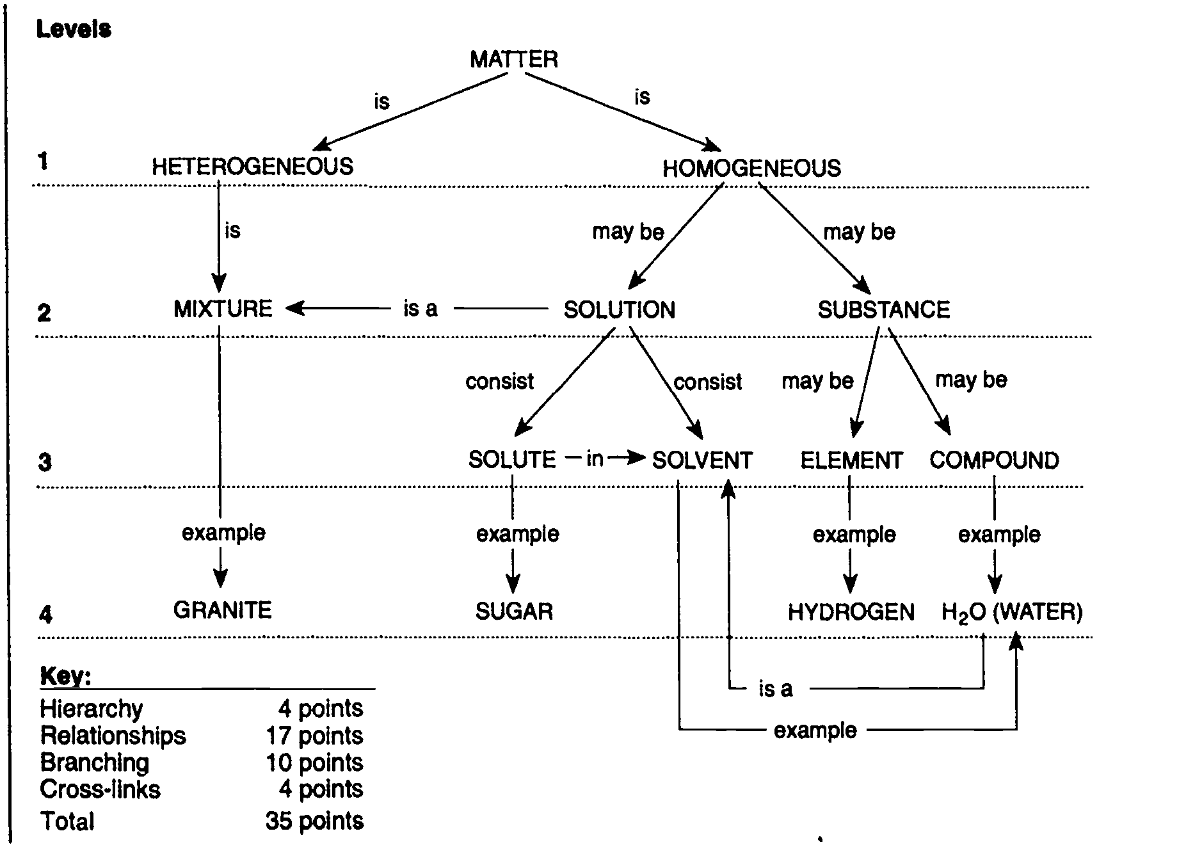
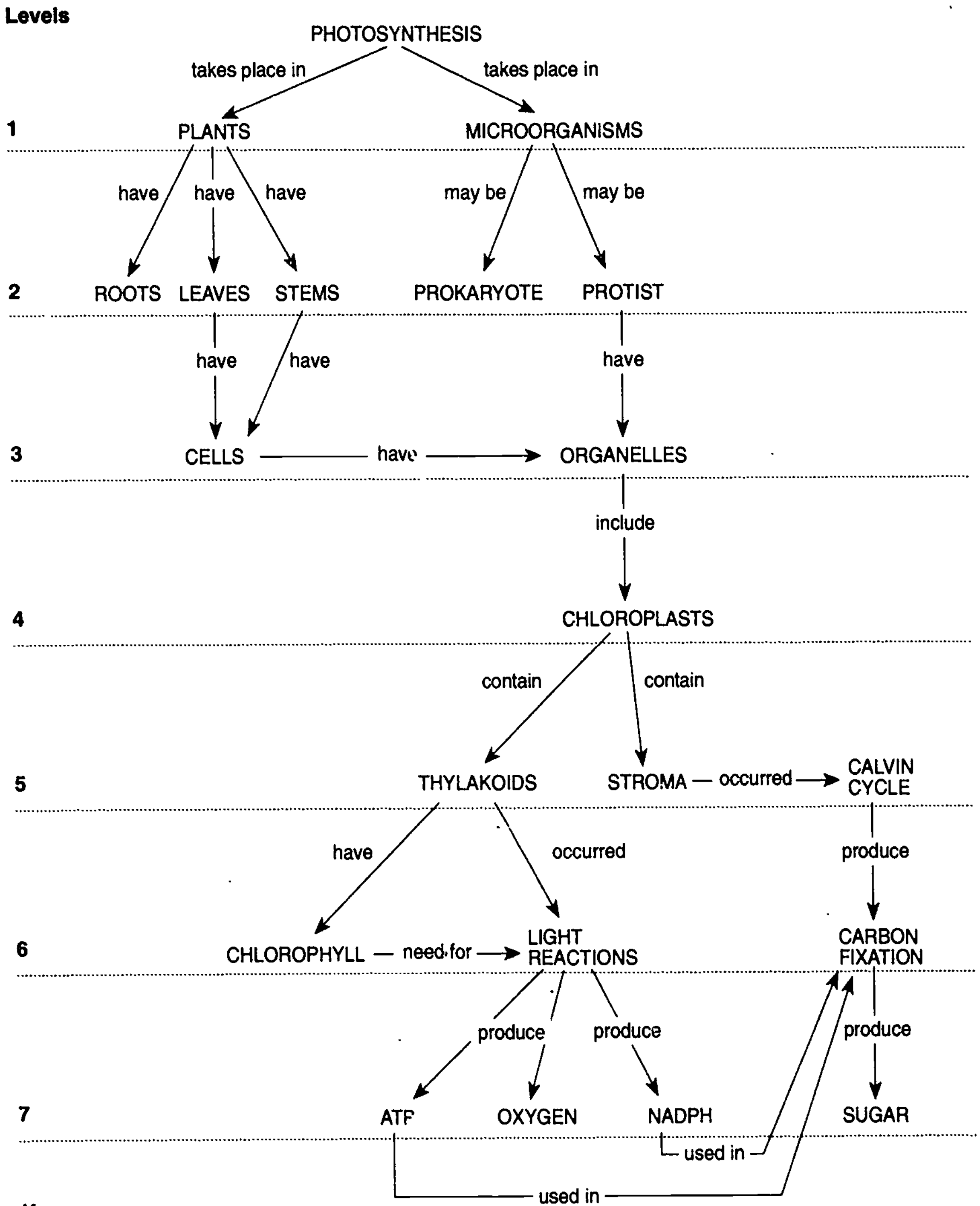


Figure 3. Concept Map About Photosynthesis



Key:

Hierarchy	7 points
Relationships	25 points
Branching	16 points
Cross-links	6 points
Total	54 points

ANGELO COLLINS

Portfolios:
Questions for Design

In a recent conversation with a colleague about using portfolios for assessment in his middle school science class, he casually stated, "Oh! A portfolio is whatever I want it to be." As I consider portfolios a new, experimental, exciting, evolving tool for teachers to use in the practice of their craft, I was taken aback. Using the metaphor of portfolio as tool, I often ask myself, "What is a portfolio? What can it be used for? How can it be used? How do teachers and their students learn to use portfolios? What can teachers and students do with portfolios that can't be done with any other teaching/learning tool? What are the dangers associated with using portfolios?" To hear someone say that a portfolio can be anything was disconcerting, to say the least. Yet the comment lurked in the back of my mind until I paused to confront it. After much reflection, I must admit that my colleague is correct, a portfolio can be anything teachers or students want—as long as they are thoughtful about what they want the portfolio to be for them.

A portfolio is defined as a container of documents that provide evidence. In the production of a portfolio, there are at least three roles to consider. The first is the portfolio designer. In a traditional classroom, this is the teacher, who states what should be included in the portfolio. The second role is the portfolio developer. In a middle school science classroom, this is the student, who completes and collects all the assignments and places them in the portfolio. The third role is the portfolio assessor, who reviews the portfolio and assigns value to the work, and by inference, to the student. Students, teachers, parents, and/or administrators may be portfolio assessors.

To aid portfolio designers, developers, and assessors in the decisions required to make the portfolio what they envision it to be, some questions need to be addressed in the portfolio process. This list of questions is not inclusive, but merely a starting point. The questions have no one right answer, but rather multiple answers. Answers will be based on context, intention, and belief; and will vary from person to person, place to place.

Evidence of what?

The first major question is, "If a portfolio is a collection of evidence, what is it evidence of?" In middle school science, the portfolio might contain evidence of what students know and are able to do—it may show evidence of having mastered and organized facts, or the mastery of some process skill such as the ability to design an experiment. Or the portfolio might provide evidence of the students' ability to work in groups, or to be metacognitive.

This first question implies a number of subquestions.

1) *Who will decide the purpose of the portfolio—the teacher, the student, student groups, or the teacher and students working together?* The teacher may decide that the purpose of the portfolio is to present evidence of science skills. Some students may decide to collect evidence of being able to observe and describe; others evidence of being able to compare and contrast; others of being able to ask questions; and still others the ability to design experiments. Alternatively, the teacher, in keeping with a district curriculum, might offer these four choices and the class decide that each will collect evidence of the ability to design experiments.

2) *Will the purpose of the portfolio be the same for all students or will it be individualized?* If the portfolio is a

good tool to display student strength, then the portfolio will be different for each student.

3) *Will the portfolio contain evidence of mastery of the purpose or progress toward the purpose with the accompanying growth and change?* If the portfolio contains evidence of the student's ability to design an experiment, will it contain the very best experiment completed during the year? Or will it contain the first experiment, which was not well designed; a later experiment with a good question and hypothesis; a still later experiment with well-organized data; an even later activity with a quality discussion; and a laboratory report from the end of the year with all good elements?

4) *What will the portfolio be used for?* Will the portfolio be used for self-reflection, for evaluation and grading, to show parents what is being done in school, for promotion to the next grade, as a culminating activity that draws together all of the science in middle school, or to assist the teacher of the next grade in planning for the needs of individual students? Or will it serve more than one purpose?

5) *When and how often will the portfolio be reviewed, and by whom?* Will students work in small groups on their portfolios once a week, will the teacher sit with each student in a portfolio review conference once a term, will portfolios be displayed for home and school night, will a public portfolio conference be part of the rite of passage from middle school to high school, or will the multi-purposed portfolio be reviewed by different people at different times?

What evidence?

The second major question is, "What will count as evidence in the portfolio?" What evidence will show that the purposes are being met? There are several possible types of evidence. One type of evidence is the materials that students usually produce in the course of instruction—worksheets, laboratory reports, book reviews, tests, and such. Another type of evidence is produced when students capture what would normally be lost—the raw data used in the lab report, the first draft of a report, diagrams or photographs of laboratory equipment, or a tape of a conversation with members of a cooperative small group. A third type of evidence is produced by someone else—a thank-you note from a community-service leader for the student's participation in a shore clean-up activity or a note that the diagrams included in a lab report were drawn by another student.

Experience has taught me that there is one form of evidence that is essential for the portfolio to be meaningful. This is a statement written by the student about how the evidence in the portfolio is related to the purpose. This may be done by attaching captions to each piece of evidence that state what the evidence is and why it is evidence. It may also be accomplished by having students write an essay about how the portfolio illustrates what they have learned. Still another technique may be to have students write a letter explaining what the portfolio contains and why it is evidence. Articulating the relationship between the evidence and the purpose is most helpful for students as they reflect on what they have learned.

Deciding what will count as evidence requires teachers to reexamine both the curriculum and instruction. If it is determined that laboratory reports will serve as evidence of students' knowledge, then reading the textbook and answering questions at the end of the chapter will not provide students with opportunities to produce evidence. If laboratory reports are deemed important evidence, the instruction must provide laboratory experiences and include writing laboratory reports.

As with the first question, this second question on what counts as evidence also implies a number of subquestions.

1) *Which pieces of evidence should be required by the teacher and which pieces may be selected by the students?* Students develop a sense of personal ownership when they make decisions about what to include in the portfolio. One solution to this question is to have the teacher determine the form—two lab reports and one concept map—and have the student determine the content—which lab reports and a map of which concepts.

2) *Which pieces of evidence must be produced alone and which can be the result of collaborative effort?* Recent pedagogical techniques include cooperative small-group work. These forms of instruction promote student participation in their own learning. Including evidence in the portfolio that has been discussed among peers

Portfolios: Questions for Design

What does the portfolio contain evidence about?

- Who decided the purpose?
- Is the purpose the same for all students?
- Will the portfolio contain evidence of proficiency or progress?
- To what uses will the portfolio be put?
- When, how often, and by whom will the portfolio be reviewed?

What will count as evidence in the portfolio?

- Which pieces of evidence are required and which are selected?
- Must evidence be produced alone or can it be collaborative?
- Will the portfolio contain only best work?
- Where will the portfolio be kept?
- How much evidence will be included in the portfolio?

promotes both peer-evaluation and self-evaluation.

3) *Will the portfolio contain only evidence of the student's best work?* While it is difficult to ask students to include poor work in the portfolio, often an early piece of work provides a stark contrast to the knowledge and skill evident in more recent work. Including what was "best evidence" at the beginning of the academic year and what is "best evidence" near the end of the year allows the student to display growth and change.

4) *Where will the portfolio be kept?* Whether the portfolio remains in the classroom or the student watches over it is a decision based on the type of classroom atmosphere the teacher is trying to maintain.

5) *How much evidence should be included in the portfolio?* The response to this question ranges fr .n everything the student has produced to a single sheet that summarizes what has been learned in science. For example, the teacher may decide that five pieces of evidence are necessary and sufficient and the student may then select which five. However, one technique called the value-added process can be used to decide how much evidence to include. Students, working in small groups in which they have established trust, select one piece of evidence as the best evidence that the purposes of the portfolio have been met. After each student has selected his or her most compelling evidence, the students then select the second most compelling evidence and discuss what is added to the value of the portfolio if this second piece of evidence is included. Students ask themselves, "What will the portfolio assessor know about me from this piece of evidence that would not be known if it were not included." A limit, although different for each student, is easily reached. Sometimes students decide that they need to collect more evidence. This value-added method promotes self-evaluation and peer-evaluation as well as evaluation by a teacher.

Portfolios are a new tool for teaching and learning science. Since portfolios may serve many purposes, science teachers have the potential to make this tool whatever they want it to be by making thoughtful decisions. And it will probably be shaped differently by different teachers ■

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LINDA NOTT
COLLEEN REEVE and
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Scoring Rubrics:
An Assessment Option

Teachers, like other humans, are judgmental creatures. We go through life evaluating events against the criteria of our preferences, standards, or experiences. Yet, we rarely assess these events the way we assess the work of our students. For example, how many of us would assign a numerical grade to a visit to the dentist's office? Most of us would more likely rate the visit on 1) the amount of time we were kept waiting, 2) the completion of the expected procedure, 3) the cost, and certainly 4) how much pain we experienced! In other words, we would assess our visit in terms of a rubric (classification system) of discrete and pertinent indicators rather than an abstract numerical representation.

If a major goal of teaching is to create students who can truly function independently, then we must reevaluate the ways we provide feedback to students in the classroom. In most instances, we tend to formally evaluate students' work only at the end of an activity or experiment. Assessment, however, must be a formative, as well as summative, tool of learning and should be central to instruction. Furthermore, if the assessment doesn't lead to valuable learning, neither the student nor the teacher benefits from it. While this assertion may seem obvious, it has specific implications about the student's role as partner in assessment rather than as a mere recipient. Students need to have concrete examples and explicit guidelines before assessment in order to compare their progress against a clearly understood standard. Additionally, they need to receive credit for making progress toward that end, rather than penalized for not succeeding immediately.

Recent research has focused on redesigning assessment methods, especially in view of the skewed publicity that standardized test scores have received. In *Curriculum and Evaluation Standards*, the National Council of Teachers of Mathematics asserts that "Teachers need to analyze continually what they are seeing and hearing and explore alternative interpretation of that information."[1] Some assessment experts have suggested alternatives such as portfolios, essays, and observation checklists. Rather than replacing unit tests or standardized tests, these alternatives are meant to complement and supplement these measures by providing information about what the student knows and can do, rather than how much the student does not know or cannot do. When constructed carefully, the alternative assessments also allow analyses of the extent of individual and group learning.

With the information explosion of today's science, the scope and sequence has become little more than a calendar for "covering" content with little time to explore topics in depth. In this system, students who memorize well succeed in obtaining good grades, but that success does not insure that the students have acquired anything of lasting value, or will succeed in their later studies.

So how do we assess what is valuable? The observations checklist is one of the easiest ways to implement a different assessment method, and it is also one of the most flexible. To ease record keeping, scoring rubrics are developed to allow students and teachers to understand what "standards" are expected. For instance, if we wanted to measure a student's progress in "drawing conclusions," we might use the rubric in Figure 1.

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Figure 1.

Drawing Conclusions

Points	Characteristics
0	Fails to reach a conclusion
1	Draws a conclusion that is not supported by data
2	Draws a conclusion that is supported by data, but fails to show any evidence for the conclusion
3	Draws a conclusions that is supported by the data and gives supporting evidence for the conclusion [2]

Not only is the scoring system easy to learn and use, but specific observable characteristics are described so that there is little room for misunderstanding or inaccurate scoring. The interscorer reliability (a strong point of standardized tests) is built into the instrument. Further, the rubric can be used again and again so that a pattern of performance can be documented to show a student's progress over time in a particular learning area. The student can "target" the standard to be achieved and can practice to become more proficient. This process allows students to assess themselves and their peers, while building self-confidence and a willingness to take charge of their own learning.

If a teacher used a scoring rubric in an activity about creating motion, it might look like Figure 2.

Figure 2.

Creating Motion

Points	Characteristics
0	Fails to participate or create desired motion
1	Creates desired motion at some designated point of the activity
2	Creates desired motion at more than half of the designated points of the activity
3	Creates designated motion at all designated points of the activity [2]

A valued skill, creating, is being measured. At the end of the grading period, the teacher's documentation shows the degree of student progress, and that can then be translated into numerical grades on a flexible scale. For instance, if the skill of creating motion was being evaluated, and the total possible points for all the creating score sheets was 36, a teacher may choose to call 28–36 points an A, 20–27 points a B, and so on. There is no mandate that a student's grade has to be a percentage value. The professional judgment of the teacher determines the final "weight" of the results.

Scoring rubrics, however, can be misused, and this must be avoided. If the rubric does not match a goal of the learning experience, or if the criteria are too vague, it has no place in the assessment program. For example Figure 3 is too vague to offer guidelines for the student or teacher. It also mixes more than one skill, even though both skills are valuable to the learning experience.

Students also need to be given the chance to show improvement in performance. They have the right to be able to produce work of which they can be proud. Therefore, a one-time use of a particular rubric is an unfair snapshot of the student's ability much like the standardized tests.[3]

When used properly, rubrics and performance checklists have great potential for providing productive feedback to students about the appropriateness of their performance. They also have the added benefits of helping educators align assessment tools with outcomes and perhaps most importantly, empower students with the knowledge they need to reach and surpass their educational goals ■

Figure 3.

Group/Cooperation Skills

Points	Characteristics
0	Does not work well in the group
1	Works well in group sometimes
2	Works well in group many times
3	Leads the group all the time

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3. Malone. V. (1991). *Promising Practices*. Paper presented at the National Science Teachers Association convention, Houston, Texas, April 1991.

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Teaching From a Global Point of View

by Victor J. Mayer

Broadening our perspective as our universe shrinks.

The 1981 launch of the space shuttle Columbia was the capstone of a long series of accomplishments that fundamentally changed our understanding of our habitat—the planet Earth. Our perception of its size had been diminishing since the time of John Glenn's orbiting of the planet, climaxing with the sight of the Earth suspended over the Moon's surface in pictures returned by the lunar expeditions. Our space exploits have provided a spectacular setting in which to consider global education and the role it should assume in science education.

Global education is a movement with a 20-year history founded primarily in social studies education. Global education has been defined as ". . . the knowledge, skills, and attitudes needed to live effectively in a world possessing limited natural resources and characterized by ethnic diversity, cultural pluralism, and increasing interdependence." As such, it incorporates aspects of environmental education as well as international education. Global education has as its central goal the establishment of cross-cultural understanding and a cooperative attitude toward world problems.

Our technical accomplishments make the achievement of such an international understanding extremely important. We will for example, be able to transport minerals from the Moon and asteroids to factories in Earth's orbit, thereby making available an abundant supply of these resources. We also will be able to obtain limitless energy from the Sun, using solar energy collectors placed in orbit by advanced versions of the space shuttle. The economic realizations of such endeavors, however, will require international cooperation.

Our ever-shrinking universe

More important than the material benefits is the expansion of the frontiers of knowledge made possible by such technological achievements. We can now see 8 billion light years into the past; halfway to the beginning of the universe. The Hubble telescope orbiting outside the Earth's atmosphere will permit us to look even further into the origins of the universe. Already we have seen sights in our own solar system that no one had predicted. The Voyager flybys of the outer planets have provided us with views of erupting volcanos on Io, a moon of Jupiter, and an immense storm system on Neptune. The advantages of international cooperation were amply demonstrated by the Soviet and European effort to obtain close-up information during the recent passage of Halley's Comet. Space programs are providing nations with a startling new perception of their place, not only in our world society, but in our solar system and our universe. At the same time, the spectacular failures of our technology, such as the Challenger disaster that took the life of Christa McCauliffe and her fellow astronauts and the Chernobyl accident which spread nuclear debris to countries around the world, remind us of

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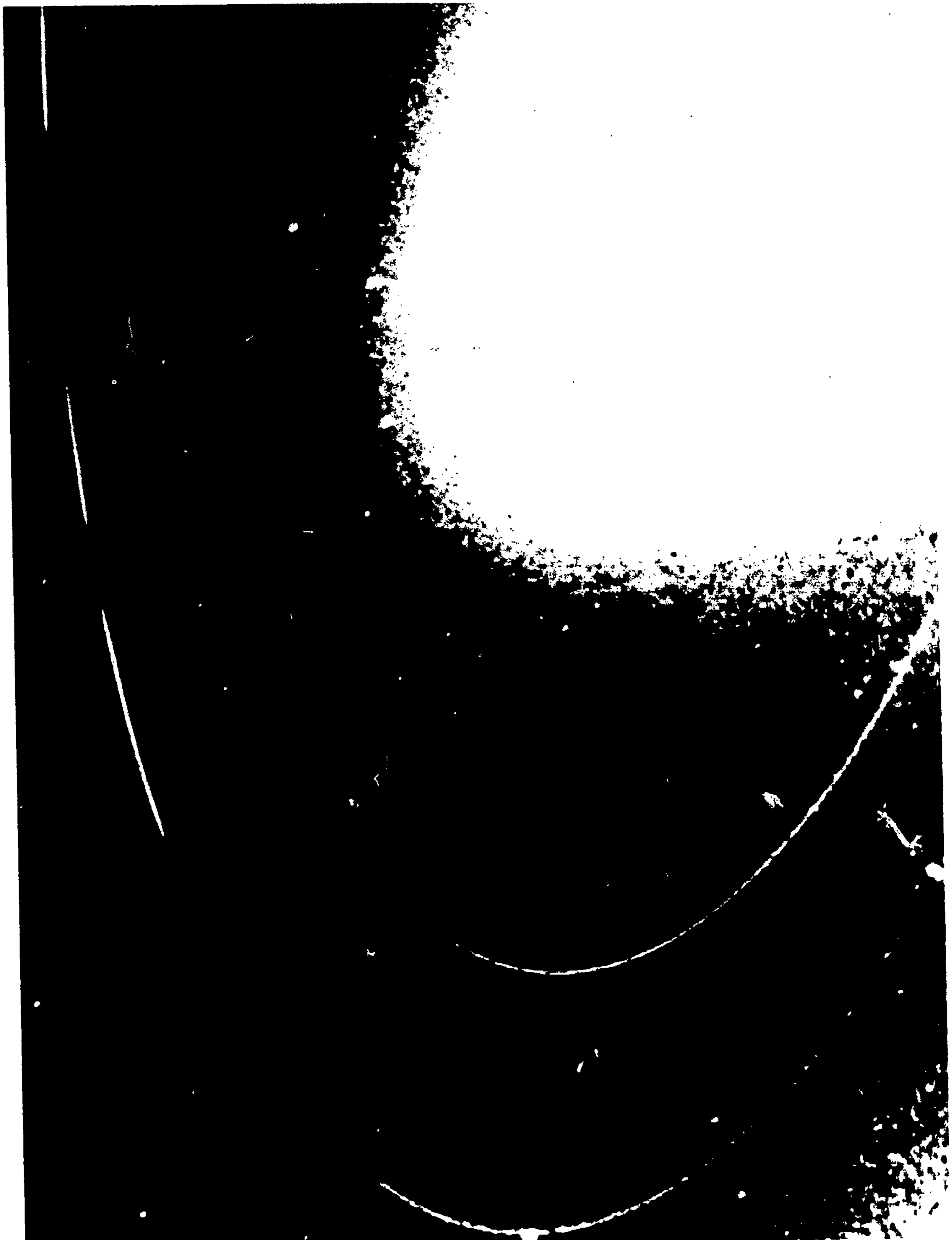

—Photo courtesy of Jet Propulsion Laboratory

the limitations of our technology, the fragility of human existence, and of the shared destiny of all nations on our planet.

Science as a model for global education

Our accomplishments and failures are technological. They result from applications of the accumulated principles and facts uncovered by the work of thousands of scientists throughout history. One of the basic problems in achieving an international understanding is the difficulty in establishing an understanding among peoples across the barriers of language and culture. Science can provide a useful model, since scientists of all languages and cultures have a subject of study in common—our Earth—and a process they use to study it.

They start with an accurate description of observations and then logically develop arguments and interpretations based on those observations. Science is a collective endeavor. Scientists will challenge each others' results and attempt to replicate them. As individuals, they possess all the frailties and fallibilities characteristic of the human state. They make mistakes. They may even intentionally falsify data. But science has correcting mechanisms. Mistakes and falsified data will be revealed by the work of others. The result of this process is a product that accurately represents nature in as far as the available evidence allows. Science, therefore, is ethical and honest. It simply seeks the best representation of the natural world. Thus, science is amoral; that is, it seeks neither right nor wrong, only the best explanation. Leaders in government, industry, business, and society select from among the principles and information made available by science. They may use it in ways others may judge as right or wrong, moral or immoral.

Satellite 1989 N1, discovered by Voyager 2 (left). *Triton from 80 000 miles* (right).

Global education should be a thread running through science curriculum.

The effects of technology

Science provides knowledge that can be used to improve our living standards. Industrial and political leaders make decisions that apply this knowledge as technology. Technology does not have the self-correcting mechanisms that science does and, therefore, lacks its ethical base. Knowledge can be used in different ways—for the long-term benefit of all, for short-term political gain, or for destructive purposes. Even when used for the most beneficial purposes, the technological use of knowledge can be destructive if the long-range results have not been considered. For example, the manner in which our leaders have responded to energy needs reflects their failure to understand the long-range implications of excessive energy consumption. Decisions have been made that maximize the short-term gain or profit from energy use but result in long-range problems. Our exploitation of fossil fuels—including coal, oil, and natural gas—has had lasting detrimental effects upon our environment. Some are readily recognized: the ravaged landscape of strip-mined areas of Ohio and West Virginia and the oil spills from damaged tankers such as the Exxon Valdez. Other effects, though more subtle, are perhaps much more threatening to our survival.

One issue of global concern is the introduction of carbon dioxide into the atmosphere through the burning of fossil fuels and the resulting enhancement of the "Greenhouse Effect." There are alternatives to the use of fossil fuels, such as nuclear energy, solar energy, and conservation. To shift our emphasis to these alternatives, however, requires understanding, commitment, and leadership.

Global education, science, and technology

The scientific approach can provide a

—Photo courtesy of Jet Propulsion Laboratory

model for achieving dialogue among peoples of different languages and divergent cultures. Thus, global education should be a thread running through science curriculum. Our future leaders and voters (today's students) must understand our interrelationships with peoples around the world and how our daily activities affect our planet and its resources. If they are to make wise decisions concerning the application of scientific information, students must realize that it can benefit or can damage the lives of all. Our leaders must be prepared to draw on scientific findings not for their own self-interest but for the sake of the common good; in the interests of all the world's people. In many ways, the science teacher can be central to

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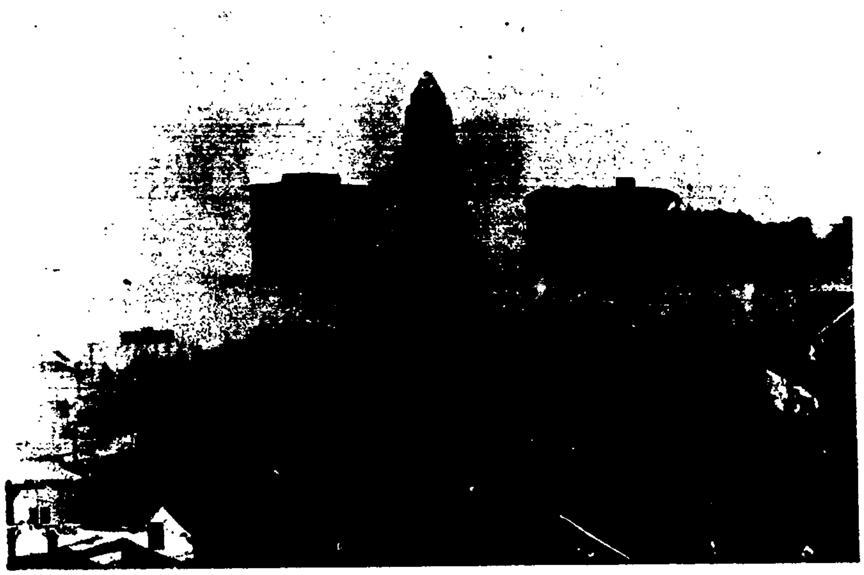


accomplishing this goal. Therefore, it is important that teachers and curriculum developers understand the goals of global education and how it relates to the science curriculum.

Including global education in science curriculum
How can you incorporate activities that lead to global understanding into your curriculum which is already overburdened? Teachers working in marine and aquatic education have developed an infusion model that could prove of some help. We have used their model in a series of investigations designed to impart marine and/or aquatic information. These activities are developed around basic topics or concepts already taught in middle school. The investigations draw upon a variety of disciplines in addition to science and social studies. They are short and self-sufficient and thereby easily inserted into existing curricula.

The investigations draw upon a variety of disciplines in addition to science and social studies.

An example of one such investigation, entitled *It's Everyone's Sea: Or Is It?*, explores the interests of different countries in using the sea as a resource. It starts with a map-reading exercise that asks students to identify topographic features of the Atlantic Ocean Basin and to locate major resources—including potential oil reserves on continental shelves, manganese nodule deposits in some of the deep ocean basins, and the major fishing areas. They also examine the position of eight countries relative to seas, ranging from landlocked nations such as Bolivia to island states such as Bermuda.

The second part of the exercise is a simulation of the Law of the Sea Conference. The class is divided into groups representing eight countries. Each delegation presents its positions on resolutions concerning the right to free passage of ships, pollution control, and the allocation of sea resources. In the third part of the investigation, students examine the manner in which international borders are designated and analyze the sources of border conflicts between Canada and the United States. Through this activity, students learn that problems of resource use are not solved merely by the technical application of scientific knowledge. Rather, solutions require informed guidance by political specialists, frequently in an international context.

Preparing teachers
We have used the infusion approach to prepare future teachers in global education. Working with one of our faculty members in social studies education, who is also a national leader in global education, we developed a series of activities and integrated them into topics normally taught during our science methods overview. They include: the nature of science, critical reading skills in science, and the use of simulations. The activities not only provide our students with a global

Students should learn to recognize the global threat posed by LA's smog (above) *and the Amazon's deforestation* (right).

perspective, but also can provide ideas for secondary school science teachers who may be trying to incorporate some of the objectives of global education into their courses. The activities take about five 2-hour long class periods.

The first activity is a review of the nature of science using an analysis of creationism and evolutionary theory as science. It begins with a presentation of the filmstrip *Scientific Methods and Values* (Hawkhill Associates, Inc., 125 E. Gilman St., Madison, WI 53703), and students read the Overton Decision (Rev. Bill McLean vs. Arkansas Board of Education, Opinion of William R. Overton, United States District Judge). The latter is discussed, emphasizing the differences between scientific theory and religious precepts. From this discussion, students develop a set of criteria that allow them to discriminate between scientific and religious ideas.

We also have the students read an article that summarizes creationists' evidence regarding the coexistence of dinosaur and human footprints (Milne, David H., and Steven D. Schafesman. "Dinosaur Tracks, Erosion Marks, and Midnight Chisel Work (But No Human Footprints) In the Cretaceous Limestone of the Paluxy River Beds, Texas." *Journal of Geological Education*. 31:111–123, 1983). Some of the teaching materials developed by the Creation Research Institute of San Diego, Calif., are analyzed using the criteria developed in

the discussion. This module helps students achieve a better understanding of science as a reasoning process and as a discipline; two aspects that are essential to an appreciation of the importance of science in global issues.

Students then view an episode of PBS's *NOVA* that focuses on Steven Jay Gould's trip to South Africa. During the program, Gould discusses the

The unit concludes with a discussion of the role of the science teacher in global education.

development of the concept of human evolution, how scientists allowed their prejudices to affect their interpretation of data, and what influences these interpretations had upon social and economic policies in certain countries. The program and subsequent discussion point out the interdependence of the world's nations and the manner in which science can be used to either cause or alleviate problems.

A rounded education

Our next section begins with a presentation of the filmstrip "Who Owns the Oceans?," which provides an overview of the various interests that nations have in the sea (Current Affairs Films, PO Box 398, 24 Danbury Rd., Wilton, CT 06897). The first two parts of the activity, *It's Everyone's Sea: Or Is It?*, described earlier in this article, are then used to point out the interdependence of nations.

An environmental section follows with two activities that demonstrate environmental problems shared by several countries. One is a simulation on acid rain that was described in the April 1984 issue of *The Science Teacher* ("The Acid Rain Debate." Bybee, Rodger, Mark Hibbs, and Eric Johnson). The other is a lab activity on the effects of atmospheric carbon dioxide and the Greenhouse Effect taken from the February/March 1986 issue of *Science Activities* ("The "Greenhouse Effect." Andrews, David).

This section concludes with a presentation of information about acid rain developed by two different sources. One is a videotape prepared by an Ohio power company, "Energy and Electricity," (NSTA/Columbus and Southern Ohio Electric Company Honors Workshop for Teachers). The other is a filmstrip set prepared by a Canadian agency, "Acid Rain: The Barriers to a Solution." (McIntyre Visual Publications, Inc., 716 Center St., New York, NY 14092). They take drastically different positions on what science has to say regarding the problems and sources of acid rain. Our students critically analyze each of the programs for emotional loading and factual errors. They also discuss the international implications of acid rain.

The unit concludes with a discussion of the role of the science teacher in global education and the techniques that can be used to integrate it into science teaching. Teachers of all disciplines, especially elementary school teachers, need to recognize the importance of science in the curriculum not simply as science per se, but in how it relates to the social, political, and economic spheres of human endeavor. We must also consider the products of science and how they can be used for the betterment or detriment of our life on Earth. We must see science as a bridge to other cultures and as a basis for communication. A focus on global education can help our students to realize that a sharing of ideas and cooperation among cultures is to the benefit of all. The science teacher can be a key figure in accomplishing this goal. ■

For further reading

Gilliom, M.E., "Global Education and the Social Studies." *Theory Into Practice*. Summer, 1981, p. 170.

Note

If you are interested in obtaining materials from "It's Everyone's Sea: Or is It?" (Mayer, Victor J., and Stephanie Ihle. Columbus. Oceanic Educational Acitivities for Great Lakes Schools, Ohio Sea Grant Program, 1981, 1987.), please contact the author for further information.

6

Resources for Implementing Earth Systems Education

In this section we provide a wealth of information on resources that will be needed to develop and implement an Earth Systems Education curriculum. First and most important are suggestions on how to obtain money from sources outside of the school system. Of course, we would really like to expect that the school system itself would be able to provide all of the money necessary to release teachers, to prepare them, to provide technology and materials, etc. But we too have lived in the "real world." Fortunately, because of the current national concern about the improvement of science and mathematics in American schools, there are many sources available. They include the National Science Foundation, the Dwight D. Eisenhower program, state environmental protection agencies, business and industry, the National Science Teachers Association, just to mention a few sources. The information provided here was developed by Carol Landis, a former PLESE staff member. We hope it will start you on the road to successful "grantsmanship."

Following that is a section that includes a bibliography of the "best" curriculum resources available for Earth Systems curricula as judged by experienced PLESE teachers, a bibliography of a variety of books to provide background information for both teacher and student, suggestions for the inclusion of music in the curriculum by Lyn Samp, one of our PLESE teachers, and finally, a list of PLESE teacher team leaders. We trust that you can find a teacher experienced in the Earth Systems philosophy, if you are not one yourself, to assist you with developing your program.

Grantmanship: Tips for Beginning Grantseekers

This section is intended to offer information to "grantseekers" by providing hints toward successful "grantsmanship" and even to suggest "grantspertise" as an addition to "grantspeak," in that expert management and administration of grant monies is evidence of true success in this competitive arena. The process can seem daunting to the novice, so this synopsis of several resources is offered as a file sheet, for quick reference as you begin to apply for grants.

So, where do you begin? Well, without sounding too obvious, it is wise to start at the beginning, which is to say that while some people may hurriedly "throw together" a grant proposal, it is wise to humble yourself and play by the rules. The rules are really quite explicit, but there are tips that might offer your proposal an advantageous characteristic that zeroes in on the target of the funding agency in the most concise, yet well presented and compelling way. Much has been written about this topic, so a synopsis of the readings is given here. A bibliographic list of frequently cited references is offered on page 67 for your further exploration of this subject.

Let's get started. Some advice to "grantseekers:" Consider your goals. What educational outcomes do you want to accomplish that can't be done now without outside financial support? This is not a wish list—it's hard–sell time! So think in terms of pedagogy and curricular development. Base your proposal on educational premises that have been given considerable thought. Be clear about your goals as you begin this process. (And when the time comes, ensure that your proposal makes these goals clear to the reviewers.)

A logical but often overlooked step is to seek assistance from a more knowledgeable person. Find someone in your district or in a supportive organization with more experience in grantseeking and a willingness to offer advice and time to assist you in your efforts. This person may be knowledgeable about grant monies already received (both locally and recently), as well as currently untapped sources. If you find that money has already been given for a similar project, plan to build on the work already begun by that funded project, explaining why and how your effort will add to the success of meeting the goals of the funding source.

Check funding sources for compatibility with your intent and to see if your situation meets their criteria; and be ready to start small. While some foundations' and organizations' grants programs are well–known, a novice in the grantseeking arena may find it productive to conduct a thorough search for lesser known sources, particularly if your needs could be met with a smaller amount of support. Many times local organizations and corporations have funds that can be appropriated more frequently and without requiring board approval. If so, contacts within these organizations can be most helpful. For instance, inquiries may be routinely directed to a single individual. When you write or call to request guidelines and application forms, it is a good idea to ask for an annual report and other documentation of their organizational goals, funding patterns, and shifts in funding priorities. Perhaps they would also supply you with a copy of a recent grant proposal that was funded. They may allow/encourage you to submit a preliminary proposal, the review of which can provide important input regarding problems (and strategies for correcting them). If so, take this opportunity seriously and prepare it carefully. Remember to express your sincere appreciation for the help that you receive (in a timely and appropriate way)!

Now the "grantsmanship" part: Write concisely. Work from an outline and use a word processor. Several times during the writing process, get an opinion from someone who has served as a grant reviewer. Be attentive to every specification outlined in the Request For Proposals ("RFP" in "grantspeak"), and be clear, yet concise. This does not mean that you should be excessively brief. Kinnamon suggests (in *Electronic Learning*, Jan. 1991) that you "exceed the minimum requirements of the grant in both content and details" while keeping within the guidelines regarding length and format. State clear objectives that describe how students will benefit. Be sure that you have considered what is necessary in order for your project to be enabled and successful...recruitment, staff (a team approach as opposed to your lone effort?), advisors, materials, TIME, phases of action, etc. Include a good evaluation plan. Produce a draft far enough in advance of submission deadlines to allow for editing and any necessary revisions resulting from critiques by your advisory group. Take time to reflect on your work (taking a few days away from it) for self–examination and consideration of any weaknesses or omissions in the presentation of the ideas. Be especially thorough in production of the budget. Get the information (such as model numbers, current prices, suppliers, handling/shipping charges, etc.) that you need and document your source. Clearly establish (and include documentation of) the willingness of an entity to act as your fiscal agent. Be sure your building principal knows about and supports your plan. Remember: proposals should be short, succinct, easy to read and to understand!

Initial conditions require that you be very familiar with the criteria for your proposal, because they will be used by the evaluators to produce the overall rating your proposal achieves. Often, components of your proposal will be given a numerical rating compounded by the "weight" assigned to each criterion.

Your goal in producing your proposal is to provide information, in as readable and clear a manner as possible, about how your efforts will meet the funder's objectives. Acknowledging that stance, then you should also:

- "Write and organize the proposal exactly to the criteria the reviewer will use in the evaluation process." If community involvement is required, it should appear in the table of contents in the correct position among the proposal guideline headings.

- Use "bullets" and other identifiers of key points to ensure that they aren't overlooked.

- At first mention, always identify an organization by its full name (listing an acronym for later use, if you wish). State the relationships among people, curricula, and organizations. Don't assume the reader is aware of your working context. Consider providing a reference list in the appendix if you have a lengthy list of organizations with acronyms.

- Be specific. Over–generalization and broad sweeping terms can mask your real purpose.

- DON'T play font–size fun! Smaller type and reduced pages are tiring to reviewers' already strained vision and concentration.

- Being specific about the evaluation methods you will use is very important. Get help if you don't feel confident in your understanding of evaluation.

- If you state that you will have assistance (partners, advisors, other schools, etc.) then document this with letters explicitly stating their intent to participate in the appendix.

- Be realistic—"a well-defined, attainable project is scored better than a grandiose one that leaves the reviewer doubting your focus and credibility."

- "Substantiate the needs for the project." Cite surveys or other documentation of the validity of your problem.

- Be specific and professional in displaying knowledge of benchmarks, national trends, etc.

- Collegiality may be critical to your success. Having people with established credibility in education (such as university liaisons) may be very helpful to your proposal.

- One last time: "Be specific!"
  Chesebrough, David. *ASTC Newsletter* March/April 1993.

Selectively produce an appendix that includes letters of support, examples of evidence documenting your ability to carry this project to its successful completion, vitae, detailed timelines, and other materials that defend your proposal. But don't bury the reader in nonessential materials. Find out if there are page limitations for the appendices!

Double check every detail and prepare cover sheets, a timeline, and data tables as required. Check every place that requires a signature. Prepare the correct number of copies and remember to back up any materials on your computer's hard drive to a floppy disk. Save a paper copy for your files. Send it in a traceable manner (UPS, Federal Express, Express Mail, return receipt requested, etc.) in order to meet the deadlines. You may wish to notify the funding source to expect your proposal. Think positive thoughts!

And now, you wait. Just in case you're curious about what happens while you're waiting, here's a brief outline of the typical handling of your proposal. Usually, the receipt of your proposal is acknowledged and it is catalogued for internal tracking purposes. There may be an internal review and a subsequent peer review process that occurs at a single location or with responses "mailed" in (either electronically or by surface courier). Analysis of these reviews is used as a basis for funding decisions, along with consideration of the area of need that the proposal meets, and the monies available for that particular need. The decision-making panel recommends funding, and action is taken to notify grantseekers of their status. This may occur weeks or months after you've submitted your proposal, so be patient.

It's not over, until it's over! When you learn the decisions regarding awards, try to get feedback. If you received funding, try to get information about the winning features of your proposal, those that were most impressive to the funding agency. If your proposal was not successful, consider that you have gained valuable experience, but also request feedback to learn even more about how you can improve your proposal in the future. And, if you revise this proposal for submission next year, be sure to state the manner in which you addressed the concerns of the reviewers. Resubmission is worth your time, since the success rate of approval the second time around is much higher.

Follow through with "grantspertise." This term refers to the expertise with which you manage the grant money and demonstrate your skills as a project administrator. Be thorough—take time to make notes to yourself about new insights you have gained (but may not remember at this time next year). Interact with other successful grant recipients and learn from their experiences. Do what you promised to do...deliver! The administration of your project, enabled by grant money, also requires attention. Document progress and stages of completion. The funding agency may require such documentation, but if not, it may prove to be useful to you in the future (as evidence of your successful efforts) for a subsequent grant proposal. Conduct formative AND summative evaluations, and act upon what is learned from those procedures.

Suggestions for successful grant administration offered in Smith's *ABC's of Grantsmanship* include the following:

1) In a project developed by a team, select one person to be the "contact" who is in touch with the funding agency.
2) Likewise, send any correspondence to a person, the contact officer, not just to an address.
3) When signing documents, always put the date and title of the person signing.
4) When submitting a continuation proposal, resubmit all required materials rather than referring to materials on file.
5) Include the identification number and project name on all correspondence.
6) Be as direct and specific as possible in all correspondence.
7) Always ask before making any changes in the budget.
8) In addition to occasional letters or phone calls to provide updates on the progress of your project, always send copies of project newsletters, year-end reports, etc. to the funding source.
9) At the completion of the project, complete and submit all required reports and statements in a timely and professional manner.

Finally, keep an idea box and contribute to it regularly. Next year when you receive the RFPs, a great idea may be there, among the many, waiting for elaboration and development...a rudimentary proposal! Grantsmanship can be both rewarding and contagious. Three central Ohio middle school teachers learned of the rewards and tribulations of a successful teacher–written proposal in their first effort at "grantsmanship." Their story follows.

ESE Middle School Field Project

Three teachers, working in the Central Ohio Earth Systems middle school curriculum project, submitted a successful proposal to the Ohio Environmental Protection Agency. The project is now operational. Shirley Brown of Clinton Middle School (Columbus City Schools), Dave Crosby of Park Street Middle School in Grove City (South–Western City Schools), and Dan Jax of Bexley Middle School (Bexley Schools) have implemented field projects for students and their parents that are focused on Understandings 1, 2, 3, 5, and 7 of the Earth Systems Education Framework.

Activities include the monitoring of the water quality of two watersheds in Central Ohio: the Alum Creek watershed which runs through a heavily developed area, and the Big Darby watershed which runs through predominantly farm and park land. Students share their data between the three schools via a computer network and analyze the differences between the two watersheds. Another component of the project is a series of field trips for students and their parents to natural areas within each of the three communities. They have also cooperated on the development and production of an activity guide to be used in teaching their Earth Systems classes.

Money from the $50,000 grant has been used to purchase computers, software, and teaching materials for the three schools; to defray field trip expenses; and to provide stipends for teachers implementing the after–school activities of the project.

Central Ohio middle school teachers take a field trip to an outdoor education location. Dan Jax, PLESE Associate Director is at left.

EISENHOWER AS A MAJOR SOURCE OF FUNDS

A major source of funds used in developing Earth Systems Education programs has been the "Eisenhower" program. As a teacher or administrator seeking to address change in your science programs, we would suggest you consider seeking funds for teacher enhancement from that source. Following is a description summarized from an article which appeared in the 1993 May/June issue of *NSTA Reports*.

The U.S. Department of Education administers the Dwight D. Eisenhower Mathematics and Science Education Program which was designed to improve the skills of teachers and the quality of instruction in science and math in both public and private elementary and secondary schools. The funds most accessible to teachers are those for activities implemented by state and local education agencies or by institutions of higher education. A top priority is support for inservice teacher training, with additional emphasis on increasing the career and instructional opportunities for underrepresented and underserved populations, as well.

About 75% of each state's funds are for elementary and secondary education and most of that money is distributed to local school districts...but the district must apply for these funds. The application may involve a teacher advisory group in the identification and statement of the needs of the district. Check with your district administration to find out what programs are currently being supported with these funds.

Funds can be used for expansion of teacher–training (including preservice and inservice training and/or retraining); recruitment and retraining of minority teachers; training related to instructional technologies (there are restrictions on the use of money to purchase equipment); integration of higher–order thinking and problem solving skills into the math and science curricula; and "mini–grants" to individual teachers for projects to improve teaching skills and/or instructional materials. The statement of the district's local priorities in its yearly plan outlines and limits what the money can be spent for during that year, so it is best to get involved in the pre–application stage when those needs are being identified.

Remember that institutions of higher education also are awarded money on a competitive basis. The money can directly benefit local schools through the development of partnerships. Applications for these grants must include a written agreement between the college or university and one or more local schools or districts. Such partnerships are especially successful if they also include nonformal education partners such as museums, laboratories, professional organizations and businesses, and industries.

What should you do? Contact your district's coordinator of Eisenhower funds. After that, contact your state's elementary and secondary Eisenhower coordinator (often someone in the state education agency or the state science/math supervisor). You should also ask who your state's higher education "IKE" coordinator is and what kinds of programs are currently being funded, as well as information about the next opportunity to apply. Ask to be placed on their mailing list! Last, but not least, talk with faculty members at a local college or university to find out if they might be interested in developing a grant proposal with you. Talk to these people first about your ideas for obtaining funds for yourself or for your school.

If you need more details, a good source is "Excerpts from the Eisenhower Mathematics and Science Education Program Regulations," available from the Eisenhower State Program (Dwight D. Eisenhower Mathematics and Science Education Program, U.S. Dept. of Education, 400 Maryland Ave. SW, Washington, DC 20202, telephone 202/401-1336). Technical assistance is also available from Triangle Coalition for Science and Technology Education, 5112 Berwyn Rd., Third Floor, College Park, MD 20740, telephone 301/220-0879.

Steering Committee for the Central Ohio Middle School Program meets to plan future activities.

Using Ike—The Marysville experience

The following contribution was adapted from an article written for the Autumn 1993, issue of the PLESE Newsletter, *PLESE Note...* It demonstrates one of the ways in which Eisenhower funds can be used in a partnership between an institution of higher education and local school districts. It was written by Bill Steele from Marysville Middle School, Marysville, OH.

The science program at the middle school had remained quite stagnant for many years. The standard "general, life, and Earth" sciences comprised our text-dictated curriculum in grades six through eight respectively. One revision of curriculum amounted to nothing more than paraphrasing the table of contents from the text selected for that particular five to ten year period. It was apparent to all department members that the time for substantive change was long overdue.

A breakthrough was achieved in 1991 when our science staff became involved in a restructuring project with middle schools from nine districts and The Ohio State University. Realizing that we shared many problems (such as lack of time to plan together, not enough materials, and dictates from "on-high"—i.e. school boards, state departments of education, etc.), the discussion among participants then moved on to see what could be done about these concerns. The project itself was a tremendous help since the entire science department from a school in each district met for more than two days a month (one school day, one Saturday, and one after school meeting) to map strategies to create a more useful and responsive curriculum. The time was well spent. We quickly arrived at the consensus that there was much more to teaching science than those things listed in a textbook. We met with many individuals with expertise in both teaching and science disciplines. We visited other schools and science education facilities such as parks and museums. Finally, we had the confidence to create our own science program to fit the needs of our students.

The "seven understandings" of Earth Systems Education provide the focus for our middle school program now. While recognizing content as being important, we have decided to place a much greater emphasis on process skills that will provide our students with the tools to learn about the world they live in, and continue to use throughout their lives. A common theme at all three grade levels will be monitoring conditions at Mill Creek Park which is being developed as an outdoor lab facility for our district. Each grade will evaluate specific elements of the area as developmentally appropriate. Data will be shared among all grades along with the local elementary schools and the other two county school systems. Likewise, similar data collected at the county schools will be shared with us. Each grade level at Marysville Middle School will also develop some individual themes. "Trees and Forests" is a grade six theme. "Ecosystems of the USA" is one for the seventh grade and "Disasters: Man-made and Natural" is a representative title for a grade eight theme. While ten to fifteen themes per grade will be developed, not all will be covered each year. Depending upon teacher expertise, materials available and current importance, a theme may or may not be covered in any particular year. At the same time, themes may be added or eliminated for the same reasons. The unifying idea behind each theme at each grade level is how it will relate to all the Earth systems — atmosphere, biosphere, hydrosphere, and lithosphere.

We are still very much in the formative stages of developing our new program. The "Earth Systems Education" concept has provided both an impetus and a focus to allow comprehensive reform to occur. Over the next several years, the program should be completed. The ESE concept is dynamic enough to allow any science program to adjust to an ever-changing school and global environment.

Feel free to contact us if you have any questions. Bill Steele, Chris Hoehn, Laura Koke, Grayce Ann Kleiber, and Kevin Sampsel, the science staff at Marysville Middle School, 833 N. Maple St., Marysville, OH 43040.

References

Solomon, Gwen (and Jack Kinnamon). 1991. "Where & How to Get Grants" *Electronic Learning*, January.

Triangle Coalition for Science and Technology Education. "GRANTS for mathematics and science education: Where to look and how to win." Eisenhower Mathematics and Science Technical Assistance Project, telephone 301/220-0879.

THE BEST SOURCES OF ACTIVITIES FOR AN EARTH SYSTEMS CURRICULUM

During the last day of the 1993 PLESE workshop in Greeley, participants were asked to identify the ten best resources for Earth Systems compatible activities at their teaching level. Each group did this, the elementary team, middle school team, and the high school team. If you had limited funds and wanted to purchase the best book shelf of reference materials for good activities — here they are. Many of the publications are available through the National Science Teachers Association. We have provided the catalog number for many of these.

Elementary School Source List

Allen, D. 1991. *Hands–On Science! 112 Easy–to–Use, High–Interest Activities for Grades 4–8*. West Nyack, NY: The Center for Applied Research in Education.

Braus, J. (ed.). 1989. *Ranger Rick's NatureScope.* Washington, DC: National Wildlife Federation. Activity titles include the following:

- *Amazing Mammals*
- *Astronomy Adventure*
- *Birds, Birds, Birds*
- *Digging into Dinosaurs*
- *Discovering Deserts*
- *Endangered Species: Wild and Rare*
- *Geology: The Active Earth*
- *Incredible Insects*
- *Let's Hear It For Herps*
- *Pollution: Problems and Solutions*
- *Rain Forest: Tropical Treasures*
- *Trees are Terrific*
- *Wading into Wetlands*
- *Wild about Weather*
- *Wild and Crafty*

Johnson, J. 1986. *Sidewalk Field Trips*. Grand Rapids, MI: Instructional Fair, Inc.

Lind, K.K. 1991. *Water, Stones, & Fossil Bones*. Washington, DC: National Science Teachers Association. (NSTA #PB089X)

Lingelback, J. (ed.). 1986. *Hands–on–Nature: Information and Activities for Exploring the Environment with Children*. Woodstock, VT: Vermont Institute of Natural Science.

Seabury, D.L. 1994. *Earth Smart*. West Nyack, NY: The Center for Applied Research in Education.

Sheehan, K. and M. Waidner. 1991. *Earth Child*. Tulsa, OK: Council Oak Books. (NSTA #OP200X)

Wiebe, A. (ed.). 1994. *Activities Integrating Math & Science, AIMS*. Fresno, CA: AIMS Education Foundation.

Elementary and Middle School Source List

Bosak, S.V. 1991. *Science is... A source book of fascinating facts, projects and activities*, 2nd edition. Richmond Hill: Scholastic Canada, Ltd.

Caduto, M.J. and J. Bruchac. 1989. *Keepers of the Earth*. Golden, CO: Fulcrum Publishing. (NSTA #OP080X1)

Caduto, M. J. and J. Bruchac. 1989. *Keepers of the Earth: Teacher's Guide*. Golden, CO: Fulcrum Publishing. (NSTA #OP080X2)

Caduto, M.J. and J. Bruchac. 1991. *Keepers of the Animals: Native American Stories and Wildlife Activities for Children*. Golden, CO: Fulcrum Publishing. (NSTA #OP080X5)

Caduto, M.J. and J. Bruchac. 1991. *Keepers of the Animals: Teacher's Guide*. Golden, CO: Fulcrum Publishing. (NSTA #OP080X6)

Project Wild Committee. 1987. *Project Wild: Aquatic Education Activities Guide*. Western Regional Environmental Education Council.

Western Regional Environmental Education Council and The American Forest Foundation. 1990. *Project Learning Tree: Activity Guide for K–6*. Western Regional Environmental Education Council.

Western Regional Environmental Education Council and The American Forest Foundation. 1990. *Project Learning Tree: Activity Guide for 7–12*. Western Regional Environmental Education Council.

Middle School Source List

Great Explorations in Mathematics and Science, *GEMS*. Berkeley, CA: Lawrence Hall of Science, Univ. of Calif., Berkeley. Activities titles include the following:

Acid Rain
Bubble Festival
Bubble Ology
Buzzing a Hive
Color Analyzers
Crime Lab Chemistry
Earth, Moon, and Stars
Experiments with Model Rockets
Fingerprinting
Frog Math: Predict, Ponder, Play
Global Warming the Greenhouse Effect
Height o Meters
Hide a Butterfly
Hot Water and Warm Homes from Sunlight
Involving Dissolving
Liquid Explorations
Mapping Fish Habitats
Of Cabbages and Chemistry
Oobleck What Do Scientists Do?
Quadice
River Cutters
To Build a House
Vitamin C Testing

(All are available from NSTA)

Gartrell, J., J. Crowder and J.C. Callister. 1989. *Earth, The Water Planet*. National Science Teachers Association. (NSTA #PB076X)

Lawrence Hall of Science. *Chemical Education for Public Understanding (CEPUP)*. Menlo Park, CA: Addison–Wesley Publishing Company. Titles include:

Chemical Survey: Solution and Pollution
Determining Threshold Limit
Investigating Chemical Processes: Your Island Factory
Investigating Ground Water: The Fruitvale Story
Toxic Waste: A Teaching Simulation
The Waste Heirarchy: Where is Away?

Project Wild Committee. 1987. *Project Wild: Aquatic Education Activities Guide*. Western Regional Environmental Education Council.

Stein, S. 1988. *The Evolution Book*. New York: Workman Publishing.

Stein, S. 1979. *The Science Book*. New York: Workman Publishing.

National Science Teachers Association. 1989. *Jason Curriculum, Grades 4–6; Grades 7–9; Grades 10–12*. Arlington, VA: NSTA.

National Science Teachers Association. 1991. *Galapagos Jason Curriculum*. Arlington, VA: NSTA.

High School Source List

American Chemical Society. 1988, 1993. *ChemCom—Chemistry in the Community*. Dubuque, IA: Kendall/Hunt Publishing Company.

Fortner, R.W. and V.J. Mayer. 1993. *Activities for the Changing Earth System*. Columbus, OH: The Ohio State University Research Foundation.

Great Explorations in Mathematics and Science, *GEMS* (see Middle School list).

Kupchella, C.F. and M.C. Hyland. 1993. *Environmental science—Living within the system of nature*. Englewood Cliffs, NJ: Prentice Hall.

O'Connor, M. and N. Chenery. 1990. *Living Lightly on the Planet, A Global Environmental Education Curriculum Guide. For Grades 7–9*. Milwaukee, WI: Schlitz Audubon Center.

O'Connor, M. and N. Chenery. 1990. *Living Lightly on the Planet, A Global Environmental Education Curriculum Guide. For Grades 10–12*. Milwaukee, WI: Schlitz Audubon Center.

Trefil, J.S. 1984. *A Scientist at the Seashore*. New York: MacMillan Publishing Company.

Yulsman, T. (ed.). 1994. *Earth*. 3(5). Kalmbach Publishing Co.

Earth Systems Education Bibliography

This is an annotated listing of books and articles that have been found to be useful in Earth Systems Education, especially in reorienting one's thinking from traditional science to a more modern perspective of the content and methodology of the science for future American needs. The books described are ones that individuals on the PLESE staff have read and found to be of interest to them. The listing is by no means exhaustive. It is heavily weighted toward literature, art, and history. The teacher will find many useful examples and images to use in classroom instruction in these books.

Accurate, Popular Writings

John McPhee. New York: Farrar, Straus, Giroux. ***The Control of Nature.*** 1989. Stories about our attempts to control nature. They include volcanic eruptions in Iceland and Hawaii, the Mississippi River, and fires and landslides in the Los Angeles mountains.

Encounters with the Archdruid. 1971. McPhee describes encounters of David Brower, long-time executive secretary of the Sierra Club, Charles Park, an exploration geologist in Wyoming, Charles Fraser, developer of Hilton Head resort area, and Floyd Dominy who, as head of the Bureau of Reclamation, has been responsible for many water impoundment projects in the West.

In Suspect Terrain. 1982. Stories that relate the controversies surrounding the acceptance of the new theory of plate tectonics; the role of geologist, Anita Harris, in those controversies, and her contributions to an understanding of Appalachian geology.

Rising from the Plains. 1986. In telling the life story of John Love, geologist who worked out the history of Wyoming, McPhee provides a vivid description of the evolution of the western landscapes, as well as an insight into the frontier life that Love experienced as a child and young man.

Basin and Range. 1980. In describing the theory of plate tectonics through a discussion of various American landscapes, especially the province in the title, McPhee relates a narrative of the history of geology as well.

Assembling California. 1993. McPhee follows his pattern of telling both the story of the professional life of a geologist and the development of the terrain the geologist studied during his career. In this case it is Eldridge Moores from the University of California. He contributed greatly to a new understanding of California as an assemblage of separate pieces of country drifting across the ocean basin to form the state.

Mark Reisner. New York: Penguin Books. ***Cadillac Desert.*** 1986.
Riesner has written a provacative description of the efforts of western landowners and politicians to establish a water policy that has provided short-term profits to individuals, but is resulting in long-term destruction of the environment and significant cost to the taxpayers of the rest of the nation.

Publications by Literate Scientists

Nigel Calder. New York: Viking Press. ***Timescale: An Atlas of the Fourth Dimension.*** 1983. This is a richly illustrated documentation of the history of our Earth and its environment in space.

Niles Eldredge. New York: Simon and Schuster, Inc. ***Time Frames: The Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibrium.*** 1985.
A fascinating account of how a careful and meticulous study of the fossil record led Eldredge and Stephen Gould to propose their revolutionary theory of Punctuated Equilibrium.

Stephen Jay Gould. New York: W.W. Norton and Co. ***The Panda's Thumb.*** 1980; ***Hen's Teeth and Horse's Toes.*** 1983; ***The Flamingo's Smile.*** 1985; ***An Urchin in the Storm.*** 1987; ***Bully for Brontosaurus.*** 1992. This is a series of books that include monthly columns published in ***Natural History Magazine.*** They range widely in topics, but most center on evolution and/or the nature of science.

Wonderful Life. 1989. A discussion of the implications of the Burgess Shale fauna for our understanding of the nature of evolution. Entertaining and informative reading on the nature of science, scientific investigation, and theory development.

John Wesley Powell. Chicago: The University of Chicago Press. *The Exploration of the Colorado River.* 1957.
Excerpts from Powell's journal of his exploration of the river include observations of the Grand Canyon and the Colorado River that can be used to teach basic concepts of erosion, sedimentation, and geological history. He was an excellent writer and one who was able to impart the excitement of scientific exploration and discovery. A newer version entitled, *Down The Colorado*, published in 1988 by Arrowood Press, New York, includes spectacular color photography by Eliot Porter.

Novels and the Earth System

Michael Critchton. New York: Alfred A. Knopf. *Jurassic Park.* 1990.
The author weaves modern developments in genetic engineering, paleontology, and chaos theory into a chilling tale which questions our reductionist, deterministic bent in science. The story evolves around the recreation of dinosaurs from DNA fragments found in fossils with the idea of creating the ultimate amusement part. As you might expect, things go terribly wrong.

Allen Eckert. Boston, MA: Little, Brown and Co. *The Frontiersman.* 1967.
Includes the story of Tecumseh and his use of comets, boloids, and the New Madrid earthquake in attempting to rally Indian tribes to battle the Americans. Has an excellent description of the great earthquake.

James A. Michener. New York: Random House. *Alaska.* 1988.
He gives very understandable explanations of how Alaska grew over the past billion years. He accurately describes the processes of plate tectonics that accounted for its formation and the recent ideas of "terranes" that geologists now think accumulated over millions of years to form the Alaskan peninsula. Michener also provides insight into the methods used by geologist to interpret the history of an area.

Centennial. 1974. He describes the evolution of the Rocky Mountains over billions of years of time. He devotes a chapter each to the development of the Rocky Mountains, the evolution of the life of the area, and the early presence of humans. Especially interesting is the section on the habitat and life of the dinosaurs that inhabited the region during the Cretaceous period. Their remains are preserved in the famous Morrison formation, which is exposed in a dramatic road cut on the outskirts of Denver.

Hawaii. 1959. He describes the evolution of the Hawaiian islands in very vivid prose, providing insight into the volcanic processes that formed and continue to mold the islands.

Edward Rutherford. New York: Ivy Books. *Sarum.* 1987.
The fictionalized story of the history of Salisbury, England. The first chapter starts the narrative during the last (Wisconsin) ice age and tells of the migration of the prehistoric inhabitants of the European continent, and how some got to what is now (post glaciation) the island of England.

Jane Smiley. New York: Ivy Books. *The Greenlanders.* 1988.
The fictionalized story of the settlement of Greenland by Icelanders and the story of their struggle in an increasingly harsher environment.

Irving Stone. New York: New American Library. **The Origin.** 1980.
A biographical novel of the life of Charles Darwin.

The Physics Community and the Real World

Luis W. Alvarez. New York: Basic Books, Inc. **Alvarez: Adventures of a Physicist.** 1987.
The autobiography of a Nobel Laureate in physics who helped in the development of the atomic bomb and involved himself deeply in the politics of science. His last major contribution to science was the impact theory for the extinction of the dinosaurs, developed with his son, a professor of geology at the University of California, Berkeley.

James Gleick. New York: Penguin Books. ***Chaos: Making a New Science.*** 1987.
The physics community is now considering nature as a subject of inquiry. A dramatic revolution is now going on in the conversion from what has been called linear science, the tradition of physics, to nonlinear science, more representative of the "real world." The author describes in readable and interesting detail this revolution and the theory behind it.

Daniel J. Kelves. Cambridge: Harvard University Press. **The Physicists.** 1987.
Kelves documents the history of science in America, starting with pre–Civil War up to the height of the Cold War (the book was orignally published in 1971). He describes the rise of the physics community in its influence on national science policy as a result of its contributions during World War I, II, and the Cold War. In the process it eclipsed the Earth science community which had achieved leadership in American science policy during the expansion of the frontier and the search for natural resources.

ART AND EARTH SYSTEMS

Art and Geology is a fascinating book, published in 1986 by Gibbs M. Smith, Inc. of Layton, Utah, that relates an impressionistic painting to the geological scene that inspired it. Rita Deanin Abbey is the artist and G. William Fiero the geologist and photographer.

Georgia O'Keefe by Nancy Frazier, published by Crescent Books, New York, in 1990, includes a portfolio of the finest works of this unique artist. They include her distinctive symbolic representations of vegetation, southwest landscapes, and city scenes. The author also provides a brief biography of O'Keefe.

The American Vision: Landscape Paintings of the United States by Malcolm Robinson, published by Portland House, New York, in 1988, is an historical review of important landscape painters and includes over 80 full color reproductions of our most important paintings.

Turner and the Sublime by Andrew Winton, is published by The University of Chicago Press, Chicago, 1980. Turner subscribed to the aesthetic theory of the sublime where a simple view, or a landscape painting, would take the observer beyond the objective reality to lift up the soul, filling it with joy and exaltation. This book includes many of his landscapes painted in this tradition.

Albert Bierstadt: Painter of the American West by Gordon Hendricks, is published by Harrison House, New York, 1988. This biography includes most of the western landscapes developed on the artist's western trips, many in full color.

The Hudson River and its Painters by John K. Howat, is published by American Legacy Press, New York, 1983. This group of American artists with its sense of national pride and deep reverence for the beauty of the Hudson River Valley portrayed their subject's spectacular cliffs and chasms, jutting rocks, vine–covered banks, and swirling waters with great and often mysterious beauty.

EXCEPTIONAL EARTH SYSTEMS PHOTOGRAPHY

Ansel Adams' work can provide images for use in classes as a source of both technical information and aesthetically pleasing views.

Ansel Adams: Classic Images is published by Little, Brown and Company, Boston, 1985. Selected by Adams during the last years of his life, the images in this book include many of his most magnificent landscapes and photographs of some of the intimate details of nature.
The Mural Project, by Peter Wright and John Armor, is published by Reverie Press, Santa Barbara, CA, 1989. Adams was commissioned in the early 1940s by the U.S. Department of Interior to take a series of photographs in the western national parks. Started but never completed because of the Second World War, his completed photographs were first presented to the public in this volume. They are accompanied by excerpts from the wilderness writings and speeches of Theodore Roosevelt.

Eliot Porter was one of our most accomplished photographers of nature. His color plates of grand views and close-up details of nature can provide the classroom teacher with both technically useful and aesthetically pleasing images for classroom use.

Eliot Porter, American Places by Wallace Stegner and Page Stegner, is published by Greenwich House, New York, 1987. It is a photographic trek across the North American Continent.

Nature's Chaos by Eliot Porter and James Gleick, is published by Viking Penguin, New York, 1990. Scientists are beginning to discover the patterns, relationships, and interactions that are present in the disorder of nature. Porter has been fascinated by this apparent regularity among the disorder, and in this book brings together many images that seem to exemplify chaos theory within nature.

Eliot Porter with photographs and text by the author, is published by New York Graphic Society Books, 1987. At 85, the author has pulled together a personal reminiscence of a lifetime of discovery, adventure, and devotion to his art. The book includes popular classics and rare never-before published images.

American Astronaut Photography: The View from Space by Ron Schick and Julia Van Haaften, is published by Clarkson N. Potter, Inc., New York, 1988. Over 120 historic images from the golden age of space exploration, taken by the astronauts, are included in this volume.

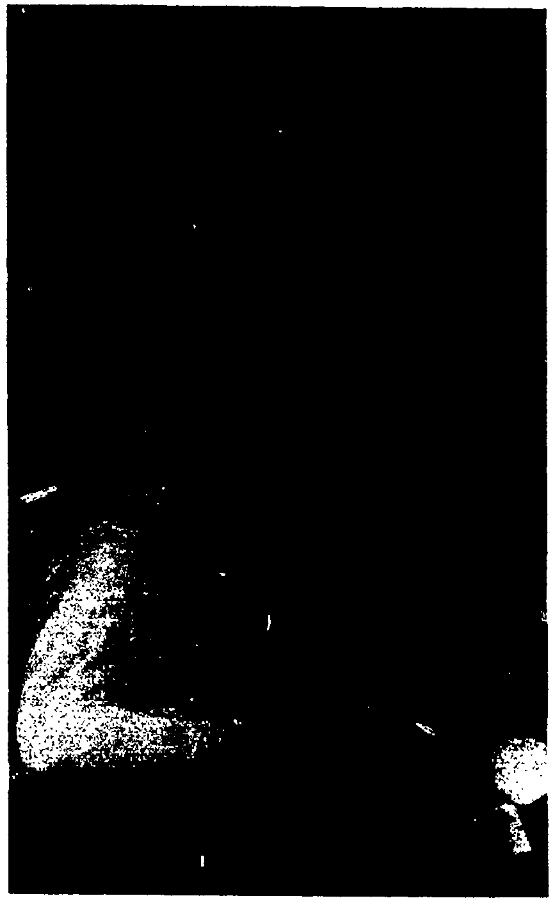
Miscellaneous Literature

The Earth Speaks by Steve Van Matre and Bill Weiler, is published by The Institute for Earth Education, Warrenville, IL, 1983. Quotes from the writings of authors such as Thoreau, Muir, and Carson capture the voice of Earth as it speaks to its inhabitants of its beauty.

Keepers of the Earth by Michael J. Caduto and Joseph Bruchac, is published by Fulcrum, Inc., Golden, CO, 1988. This book is a collection of North American Indian stories with related hands-on activities designed to help readers feel a part of their surroundings.

A Far Side Collection: Unnatural Selections by Gary Larson, is published by Andrews and McMeel, Kansas City, 1991. This collection of his recent cartoons includes Larson's interpretation of the evolution of life on Earth in five double-page color panels.

Scientific Progress Goes "Boink" by Bill Watterson, is published by Andrews and McMeel, Kansas City, 1991. This collection of the adventures of Calvin and Hobbes includes their photographic excursion to the Jurassic, and Calvin's trips to several planets.



Mark Maley, BESS teacher, confers with one of his students.

Music as an Aesthetic Medium for Teaching Earth Systems

The following was written by Lyn Samp, participant in the 1991 PLESE workshop in Columbus. She provides a variety of ideas on how to use music in an Earth Systems class and a list of music she has found useful in her high school classes.

Music is a wonderful mechanism for evoking interest in science because virtually everyone loves music, people can express individuality through sharing their favorite music, and because infinite pieces are forever inspired by Earth and its systems.

Suggestions for Classroom Use

Materials

Keep a **tape/CD player** handy in the classroom. Allowing freedom of expression will encourage more participation, variety, and excitement.

Have ongoing **song lists** available in the form of charts around the room. As students come up with a piece, they can add it to the list, along with the artist and their own name so that they can receive credit for the idea.

Make the **lyrics** available. Students are good resources for this.

Provide **drawing materials** for students to express themselves during interpretation. Post the artwork around the school or classroom.

Lessons

Students enjoy making their own personal lists and keeping them in their notebook or portfolio. The list grows over time as new songs are experienced or old songs remembered.

Interpret songs, but be careful...music videos have already pre–interpreted many popular songs, such as "November Rain" (Guns N' Roses). This is a problem because it stifles student creativity. I've been told, "I already know what the song is about, because I saw it on MTV."

Performing music is another way in which students can express their music. One student sang "Wind Beneath My Wings" at a spirit assembly promoting the team name "Zephyr." The school orchestra performs "Night on the Bare Mountain" (Mussorgsky) for the science classes.

The students delight in sharing their own music, but you may wish to preview it for appropriateness. Give your students' music a chance, and they will be more likely to keep an open mind when you expose them to unfamiliar numbers. My students have turned me on to several new music pieces which I now listen to on my own and have in my personal collection. Take advantage of the classic rock revival which finds many students, teachers, and parents today with similar music tastes.

Play "the song of the week." This can be chosen by various criteria...a new song, an especially Earth System–inspired song, a particularly beautiful piece, whatever.

I have collected, with the input of students, several tapes of background selections for playing during labs and activities. The students can select one song of their own or one from the tape to set a mood *before* or *after* the activity. Or, while the students are plotting the orbit of the moon, for instance, play a "Moon Songs" tape in the background. As the next song comes on, write the name and the artist on the board. Compile tapes entitled "Stars and Sun," "Planets," "Earthquake Songs," "Rock Music," "Water Music," or any suitable topic, and infuse music into your existing curriculum.

Students often get ideas for music from their parents (and parents appreciate being involved). They regularly bring in medleys which include pieces suggested by other family members.

The following is an interpretation which I use with "Riders on the Storm" (The Doors). This works well after the students have had a chance to share their own music. It is effective before, during, or as a follow–up to a storms unit.

Using Riders on the Storm as an Aesthetic Medium

(An example of how music can be used in a science lesson.)

Materials

Boom box (or other suitable stereo system)
Recording of *Riders on the Storm* by the Doors
Drawing Paper
"Expression" materials: crayons, markers, etc.
Copy of the lyrics (one copy per person)

Setting:

A comfortable room, with the lights dimmed

Before the music starts:
Relax, maybe close your eyes
Think about your own personal experiences with storms

During the music:

Follow the words along, if you wish

Listen to the song
-the music,
-the background effects,
-the words

Express your reactions to the song, using the materials provided.

Draw, write down words which come to mind, identify feelings elicited, and so on.

After the music:

Did you like the song?
How did the song make you feel?
What kinds of storms are represented?
What does it mean to "ride" a storm?
Which sounds from the music relate to storms?
How do the words themselves relate to storms?
What comparison(s) can you make between life and storms?

This activity should be used as an introduction, or perhaps followup, to a science lesson or unit on weather and storms.

Selected Music for Use in Earth Systems Classes

The following is my personal list, with additions from friends, colleagues, and students. The list is never complete, so information gets added bit by bit. This list has evolved and become more varied over the years, yet it is lacking in some styles, such as Country and Western. Someone else's list of musical tributes to Earth Systems would surely look very different from this one.

Lithosphere

Ain't No Mountain High Enough...Marvin Gaye and Tammi Terrell / Diana Ross
Allentown...Billy Joel
Climb Every Mountain...from The Sound of Music
Eruption...Van Halen
Heart of Stone...Rolling Stones
I am a Rock...Simon and Garfunkel
Like a Rock...Bob Seger
Mahlenburg County...J. Prine
Papa Was a Rolling Stone...Temptations
Rock Around the Clock...Bill Haley and the Comets
Rocky Mountain High...John Denver
Rocky Mountain Suite...John Denver
Solid as a Rock...
Stoned Love...Supremes
Thank You...Led Zeppelin (a beautiful song which ties love to Earth processes)
The Flower That Shattered the Stone...John Denver
Turn To Stone...Black Sabbath
Volcano...Jimmy Buffet
Wild Places...Dan Folgleberg

Stars

Catch a Star...Men at Work
Everybody is a Star...Sly and the Family Stone
Good Morning Starshine...Oliver
Seventh Star...Black Sabbath
Shining Star...Earth, Wind and Fire
Shooting Star...Bad Company

Moon

Bad Moon Risin'...Creedence Clearwater Revival
Blue Moon...Sha Na Na
Brain Damage/Eclipse...Pink Floyd
Moon River...Henry Mancini
Moon Shadow...Cat Stevens
Moondance...Van Morrison

Moonlight Sonata...Beethoven
Rocket Man...Elton John
Shad... 'n the Moonlight...Anne Murray
Space Oddity...David Bowie
There's a Moon Out Tonight...Capris

Atmosphere/seasons
Appalachian Spring...Copeland
Blowin' in the Wind...Bob Dylan / Peter, Paul and Mary
Breathe in the Air...Pink Floyd
Catch the Wind...Donovan
Cloud Nine...Temptations
Cloudy...Simon and Garfunkel
First Of May...Bee Gees
Get Off of My Cloud...Rolling Stones
I Think it's Going to Rain...Joe Cocker
I Wish it Would Rain...Temptations
In The Summertime...Mungo Jerry
Kentucky Rain...Elvis Presley
November Rain...Guns N' Roses
Pieces of April...Three Dog Night
Raindrops Keep Falling on My Head...B.J. Thomas
Rainy Days and Mondays...Carpenters
Running Against the Wind...Bob Seger
Save it for a Rainy Day...Stephen Bishop
Seasons of Wither...Aerosmith
Summer in the City...Lovin' Spoonful
Summer...War
Summertime...from Porgy and Bess
The Four Seasons...Vivaldi
Theme from "The Greatest American Hero"
Thunder Rolls...Garth Brooks
Wind Beneath My Wings...Bette Midler
Windy...The Association

Cryosphere
Cold Hearted Woman
Frosty the Snowman
High Country Snows...Dan Fogleberg
Ice, Ice Baby...Vanilla Ice
Let it Snow
Winter Wonderland

Planets
Earth...Dweezil Zappa
Jupiter's Child...Steppenwolf
Jupiter...Earth, Wind and Fire
The Earth is a Spaceship...Douglas Wood
The Planets...Holst (parts are especially good for calming the class)
Third Stone From the Sun...Jimi Hendrix
This Island Earth...The Nylons
This Pretty Planet
Turn, Turn, Turn...Byrds
Venus in Blue Jeans...Jimmy Clanton
Venus...The Shocking Blue / Frankie Avalon

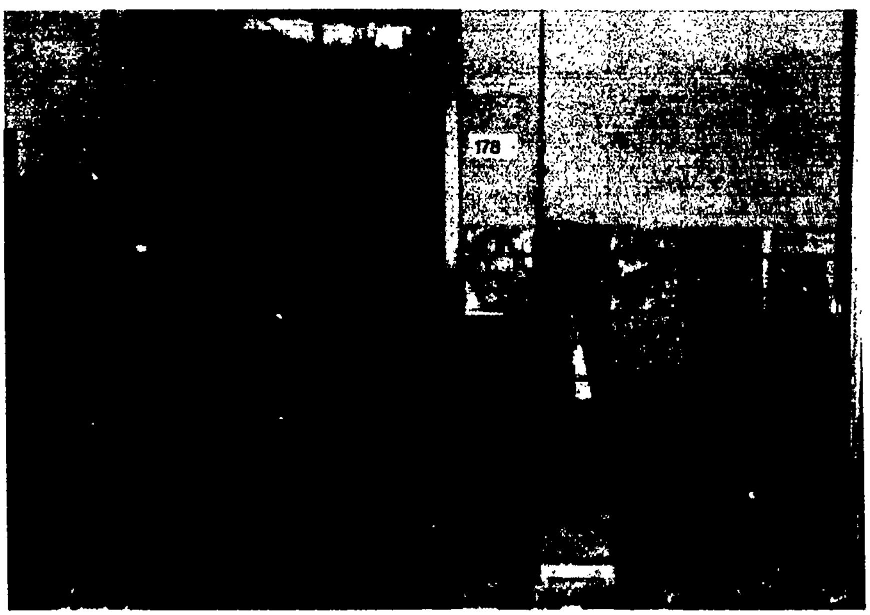
Sun
Aquarius/Let the Sun Shine...The 5th Dimension
Don't Let the Sun Catch You Crying...Gerry & the Pacemakers
Don't Let the Sun Go Down on Me...Elton John and George Michael
Here Comes the Sun...Beatles
House of the Rising Sun...Animals
I'll Follow the Sun...Beatles
Sunny
Sunshine of Your Love...Cream
Sunshine on My Shoulders...John Denver
The Sun Ain't Gonna Shine Any More...Walker Brothers
Waiting for the Sun...Doors
You Are the Sunshine of My Life...Stevie Wonder
You are my Sunshine

Biosphere
Bungle in the Jungle...Jethro Tull
Dead Skunk in the Middle of the Road...Loudon Wainwright
Dog and Butterfly...Heart
Freebird...Lynyrd Skynard
Garden Song...John Denver
Habitat...Bill Oliver
Horse With No Name...America
If I Could Talk to the Animals...from Dr. Doolittle
Joy to the World/Jeremiah Was a Bullfrog...3 Dog Night
Muskrat Love...Carpenters
Ode to Be Blue...Gordon Lightfoot
Oklahoma...from the musical
Peter and the Wolf...Prokofiev
Requiem For the Whales...Crosby and Nash
Shock the Monkey...Peter Gabriel
The Eagle and the Hawk...John Denver
The Rose...Bette Midler
Three Little Birds...Bob Marley and the Wailers
Wheat Fields...John Denver

General/enlightenment/interactions
America the Beautiful
Bones in the Sky...Dan Fogleberg

Circle of Life...Elton John (from The Lion King)
Earth Songs...a whole collection by John Denver
From a Distance...Nancy Griffith / Bette Midler
Over the Rainbow...Judy Garland (from The Wizard of Oz)
Rain Forest Rap
The Sound of Music...from the musical
This Land is Your Land...Woody Guthrie
Wonderful World...Louis Armstrong
any music by Yani Stuf

Hydrosphere
Brandy...Looking Glass
Bridge Over Troubled Water...Simon and Garfunkel
Calypso...John Denver
Cry Me a River...Joe Cocker
Dock of the Bay...Otis Redding
Down By the Sea...Men at Work
Green River...Creedence Clearwater Revival
I Am The Sea...The Who
Old Cape Cod...Patti Page
Proud Mary...Creedence Clearwater Revival / Ike and Tina Turner
River Deep, Mountain High...Ike and Tina Turner
Sitting in an Ocean...Stephen Bishop
The Maul Dance...Schubert
The Ocean...Led Zeppelin
The River is Wide...The Grass Roots
The River...Garth Brooks
Woolly Swamp...Charlie Daniels
Wreck of the Edmund Fitzgerald...Gordon Lightfoot


Instead of a text, the BESS students use journals, magazines, videodiscs, CompuServe and other modem sources of information.

Following are pieces of my own favorite Earth–inspired music that I have collected for use in my classes:

Circle of Life...Elton John
November Rain...Guns N' Roses
Moondance...Van Morrison
Over the Rainbow...Judy Garland
Jupiter...Holst
Dog and Butterfly...Heart
Ain't No Mountain High Enough...Gaye and Terrell
Don't Let the Sun Go Down on Me...Elton John and George Michael
Brain Damage/Eclipse...Pink Floyd
Proud Mary...Creedence Clearwater Revival
Thank You...Led Zeppelin
Everybody is a Star...Sly and the Family Stone
Autumn...Vivaldi
I am a Rock...Simon and Garfunkel
The Rose...Bette Midler
Volcano...Jimmy Buffet
Sunshine on My Shoulders...John Denver
Freebird...Lynyrd Skynard

Enough music is out there for putting together any style of tape..."Classical Tributes to Earth Systems" could include Flight of the Bumblebee (Rimsky/Korsakov) and Spring Song (Mendelssohn) along with selections already mentioned. Other possible themes: "Earth Systems Rock Music," "Soul of the Earth," "Earth Music for Easy Listening,"...the sky's the limit.

I hope that you will be able to use some of the suggested music here in your classes, and that it will help to stimulate more interest among your students in science and a study of our Earth systems.
—Lyn Samp

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South Carolina 2
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Special Virginia (& Tennessee)
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Virginia
Helen Marie Boothe
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Bill Hoyt, Western Center PLESE Director preparing the main course at a cookout in Rocky Mountain National Park.

7

Conducting Earth Systems Education Workshops

The first part of this section is adapted from suggestions for teacher–conducted workshops prepared for the PLESE program by Rosanne Fortner.

Introduction

So you have agreed to "do" a workshop, but for all your good intentions you really don't know what you're getting into? Have you been to the good, the bad, and the ugly as far as workshops go? Surely you want your workshop to be remembered among the good, but how can you assure that this will happen?

[illegible]

Are you prepared for these implications? A well designed and implemented workshop can be an excellent means of introducing innovations into the curriculum, providing you with contacts among support groups, and developing a network of colleagues who, like you, are interested in improving the work schools are doing. A poorly planned workshop is a personal and institutional embarrassment, as well as a waste of time and money.

It's time to begin thinking of the how, when, and where of your workshop, assuming you already know the what and why. Buckle your armor, then, and get ready for a personally demanding but professionally rewarding experience.

We invite you to plan your workshop based on the suggestions of educators who for twenty years have conducted numerous such events for varied groups and purposes. We have tried to anticipate the most common concerns of the workshop developer as we assembled this manual, but we may have missed some. Please feel free to suggest additions that will make the material useful for more circumstances.

The workshops described here are of two kinds: 1) sessions at professional conferences, and 2) longer workshops that are stand–alone events requiring targeted recruitment, space arrangements, and other logistics.

Which kind of workshop?

The Type 1 workshop is most common for beginners and may serve many purposes very well. We consider it an awareness workshop, because its length doesn't allow for in–depth presentation and involvement. This kind of workshop is ideal for whetting apetites, describing programs, and presenting innovative activities.

Type 2 workshops are exploration workshops that give you time to develop ideas more fully, immerse your audience in concepts, and involve them in a variety of different ways of approaching the curriculum innovation you are introducing.

There is a Type 3 workshop too, a subset of Type 2, for implementation or adoption of innovations. This type is much longer and more involved, lasting perhaps a week or two or spanning a school term with weekly meetings. For this type, some methodological ideas are offered.

Participants at an NSTA workshop conducted by the North Carolina PLESE team.

Scheduling

If your workshop is part of a professional conference (Type 1 Workshop), you may have little control over when you are scheduled. Request at least a one-hour block to allow for a variety of activities and time to respond to questions. If the conference program comes out with yours scheduled as the first morning session (8 am) or the last session of the conference, expect that fewer participants will appear. Some of this scheduling disadvantage can be overcome with creative advertising, however, following some of the suggestions below.

If you have a choice about when to conduct your longer type of workshop (Type 2), you should be aware of a few guidelines:

- spring Saturdays draw low participation
- participation can be as high during school hours on a weekday as on a Saturday, if you are assured of school system cooperation,
- avoid holiday weeks and grading periods
- avoid Friday afternoons
- be alert to faculty meeting days
- take advantage of scheduled in–service days
- be sure the facilities you need will be available and open when you need them.

In addition to choosing a day and time, you will also need to plan for the space for your meeting. Being in one room for an entire half day or longer can become very uncomfortable. Plan to move your participants around: room to room, library to gym, large group to small groups, indoors to outdoors. Get rooms that have windows to use as activity rooms, and interior rooms for slide shows. Post more signs than you think you need to direct people from the parking lot to the area for the first meeting. Be sure custodial care is available after the group leaves.

In sessions all day? Schedule a coffee/juice break after the first hour, and a soft drink break in mid afternoon. Who does lunch?

Your best support for scheduling this type of workshop is an administrator who will be aware of the full calendar as well as sensitive to the importance of the in–service program you are presenting. This person, who is convinced of the value of your efforts for the entire district or other group of targeted teachers, should be willing to facilitate those efforts to the extent possible within the system.

Advertising

Conference session descriptions

In the 25 words or less that most conference organizers allow you for a description of your proposed session, you must make it sound exciting and attractive to your target teachers. Your session proposal should:

- specify the target group by grade level or subject area, to avoid midstream dropouts who find the session just isn't what they expected
- be specific about what you will do (demonstration, multimedia show, labs, etc.)
- indicate if it is "hands–on," a real attention–getter in a conference program
- mention if free materials will be distributed (beyond the standard handout type).

To enliven your proposal, try beginning with a question or an outrageous statement. Use a play on words, or a hot buzzword if appropriate. Some examples are included here for ideas.

"Oh, say can you see . . . " questions a visitor to the Great Smoky Mountains. You would be surprised to find that Sequoia National Park lies in the second dirtiest airshed in the United States. I'll share the results of a year–long program of materials development for air quality education and interpretation within the National Park Service. (Ecol)

Air Quality in the U.S. National Parks
Rosanne W. Fortner
Ohio State University, Columbus

The Great Lakes Triangle has more unexplained disappearances than the Bermuda Triangle. Let's investigate them with earth science and science process. Free curriculum materials! (Earth)

The Great Lakes Triangle and Other Mysteries
(Middle/Junior High)
Rosanne W. Fortner
Ohio State University, Columbus

Caution: If you advertise free materials, some people will come only for that. Distribute only what you are really presenting, because research shows teachers don't often use what they haven't been trained to use! Be sure you have plenty of copies, and spread the distribution through the entire session so that earlybirds and latecomers can't dash in and pick up the whole pile without attending the presentation. If you run out of materials, pass around a sign up sheet for those who were left out, and send them the materials very soon. Good will is lost for your program if you don't deliver what you say.

Timing of your advertisement (the conference description that will appear in the program) is determined by the conference's Program Chair, and sometimes it must be submitted 8–10 months in advance of the meeting. If your proposal is late, you can sometimes get on the program with a call to this person to explain the exciting session you have to offer. At this point you are the beggar. Apologize for missing the deadline and accept whatever program slot is available if you can.

Advertising exploration workshops. To attract teachers to longer workshops requires a concentrated advertising effort. Teachers are busy people, and many groups want their attention for curriculum innovations. The support of an administrator and a local college educator will be valuable in getting participants for these programs. These individuals can identify potential teachers and get information to them efficiently. They frequently have access to distribution systems (newsletters, couriers, electronic bulletin boards) that will cost you nothing and will avoid the problem of "information short–stop" on the desk of a principal or other busy individual.

It is still your responsibility to develop the material that the support people can distribute. An attractive flyer or simple brochure is sufficient. Be sure to include the when, where, and how much (if you have fees). Use the same kind of excitement as you would in a conference proposal, and only a few more words! Add clip art, perhaps your administrator's quote to encourage participation, and a contact to provide further information. Include any registration form you require — don't wait to be asked for it. In addition to distribution through college educators and administrators, use existing information channels for teachers. Develop a short news release (your flyer might work) and send it to district teachers' newsletters and the local ETV channel. If you use an electronic bulletin board, list your workshop there and yourself as the contact.

Timing for these advertisements is critical, especially if you are asking for registrations in order to plan for the correct number and grade level of participants. For sanity and planning purposes, this information is needed about 2 weeks before the workshop, so notices have to go out at least 4 weeks in advance. If the workshop is on a school day or is in competition for in–service time, an earlier advertisement is necessary so teachers can arrange their time.

Recruiting and Registration

These are issues only in Type 2 workshops and longer ones. If you have a whole day of activities to organize, you need to know who's coming and how many of them. Your original advertisement should contain a registration form to be returned by a certain date because "enrollment is limited." A sample is attached. Be sure to collect all the information you need to respond to the person who registers and to prepare for that person's participation.

This is a job for a knowledgeable supporter of your efforts, one who has a ready phone and is able to answer tough questions from potential participants. We recommend the administrator you have identified, or that person's close assistant. You should be informed of progress in registration regularly. Set a time every other day when you will expect a call from your liaison.

To fee or not to fee. You are making a great investment of personal energy and professional time for this workshop. Numbers of people are depending on you and expecting things to happen. You can't rely on guesswork about how many lunches to order or materials to duplicate. The no–show rate for free workshops can exceed 20% of those who send in a registration form!

For these and other reasons, we recommend a fee for registration for longer workshops. A teacher who pays $10 has made a commitment to be present, even if it's raining hard and there are still more

papers to grade before Monday. Even if you don't need money for the materials you plan to distribute or things you want to do, use it for lunches and breaks. Buy a nice folder for participants to carry their materials in. The workshop will be so exciting that they will consider it a bargain at almost any price!

Staffing

You are clearly the best person to be presenting this workshop, but they don't give purple hearts to overworked teachers. Get a helper or two — other teachers you trust to do a good job, and possibly an aide to go-fer while the workshop is in progress. During the schedule of activities, alternate responsibilities and divide the group occasionally so one person is not always the center of attention, and one doesn't get all the work. Even if the other staff don't do things exactly as you would do them, be openly appreciative of their efforts. At least you didn't have to do it all yourself.

Selection and Sequencing of Content

Basics
The workshop should have ONE major goal, and only a very few objectives based on the amount of time you have. List these in advance so the staff knows the bottom line. If time is short, these are the things that MUST get accomplished. Select all your program segments to build toward the goal. Make it clear as you begin your presentation that you have this reason for being there, and be prepared for some to leave if that goal is not why they came.

Buildup
Start off with an intro that grabs your audience and won't let go: tell a mystery story and withold the ending; do a quick and flashy demonstration; or hand out some strange items and let participants figure out how they are related to your topic. High school teachers often prefer some quotable gee–whiz facts instead of drama. Use your imagination to capture theirs, but don't become so involved in theatrics that you forget your serious goal.

Clinchers
A carefully crafted workshop lays out several pieces of a plan, then fits them all neatly together. It's the total effect you want teachers to remember. Plan to have a summary of some kind: transparency that relists key points or ideas, or a handout with the same.

"One for the road" is also a valuable concept: send them out with your message just ready to be told to someone else. Put your science in a song or a rap, and send them out after they help perform it. Give them some of your demonstration material so they can show people in the hall. Hold a final drawing and give away some additional materials. This is your last chance — make it stick!

Sequencing and pacing
In addition to keeping the above in order, pay attention to the pacing and flow of events in your workshop. Like their students, teachers have an attention span that is limited to a very short period. Higher grades, longer attention, but only to a point. To keep a workshop moving and emerge with an excited audience instead of an exhausted one, vary the length of workshop components and the type of activity you schedule. Suggestions:

- no two slide programs back to back
- alternate presenters
- no program segment over 45 minutes long (20–30 is better)
- alternate listening segments and activities
- move people around for groups, games, etc.
- follow heavy lectures with lighter activity
- officially break after every 1.5–2 hours.

A sample 1.5 day agenda developed by PLESE teachers is included at the end of the section. Refer to it for ideas.

Participants in an ESE workshop at an NSTA conference in New Orleans, conducted by PLESE participants.

Flexibility — when and how

The conference presentation just before your Type I workshop went 15 minutes overtime and really cut into your time slot! A lightning storm interrupted the live weather satellite feed you had just started. The phone line they gave you for the modem demo won't allow a long distance call! No amount of grumbling and inner frustration will change these situations, so relax and salvage what you can. Cardiac arrest could slow you down too! Remember your main goal and objectives, and go for them with vigor. You are still responsible to the next presenter to end your show on time.

Be alert to your own energy level, and aware that your participants are less involved than you are. If you are tiring, they are more tired. Teachers will let you know if they are not comfortable with some part of the program. Take their needs seriously and respond by juggling program components or altering the method of presentation. Even if your efforts don't solve the problem completely, the attempt will be acknowledged and appreciated.

Your workshop should move briskly, but should allow for feedback too. When attention is flagging, regain involvement by asking questions or inviting some. It has been said that the mind can only absorb what the seat can endure. Look ahead to other program components and judge how they will fare under existing conditions. It is better to quit early than to hold onto your program plan in spite of participant comfort. Don't let their last impression be one of relief!

Handouts and Offers

One of the most valuable things you can have on hand for workshops, mail requests, and drop–in questions about your topic is an attractive fact sheet that answers the most asked questions. Parks and nature centers use these very effectively. If you haven't seen them, be sure to gather some examples on your next outing. They will save you hours of personal time and will have a carry–home value that extends what you can do in a workshop. If you make your own fact sheet, use a desktop publishing program. Keep the verbage light, the type size readable, and the graphics clean. The Earth Systems program fact sheet in section I provides some ideas.

Other handouts may be valuable for workshop distribution, to guide the activities in progress or to provide background and ideas for extensions. If you develop original materials, assume others will copy and use them. Put your © on them if you intend to copyright, but at least put your name or organizational source, with an address, on the first page of each part. This way users can contact you with questions, and you'll also have credit whenever they copy and use the material.

Be sure to observe copyright regulations. If it's not your original material you have only a few choices:

- Rewrite it in a new way, shorter or in a different context, with credit to the original.
- Use the ideas, make visual aids, and talk about the material, but distribute nothing. Provide information about the original so it can be procured if desired.
- Contact the original source and get permission to use the material as is, with a credit line.

Some of the material you use in a workshop will not be possible to distribute because of size, ownership or cost. Develop or secure order forms for items that your participants can request on their own. Don't try to become a warehouse or distributor for materials. This is a thankless job full of headaches, and it's not in your job description! Workshop participants want a personal copy of everything, but if they are responsible for procurement, they are more selective and materials are more likely to be used.

Distribute a sign up sheet only for materials that you ran out of, or materials that are not quite ready yet (and you'll send order forms later). Invite people to write to you or your workshop sponsor with specific questions. Whenever possible, put the burden of contact on the participants. Sincere ones will do it.

Evaluation

Evaluation is an on–going process, not a last step. Several formative evaluation notes are built into the preceding sections of this guide. Those factors that are assessed in midstream are the ones used to guide the progress of the workshop and assure that it is continually meeting its objectives.

This section will focus on summative evaluation, which incidentally occurs at the end of the workshop but has been planned as an integral part all the way along.

Countable factors. The easiest things to evaluate are the ones you can count:

- number of participants
- number of orders received or materials distributed
- additional requests for information

Judgement calls. Estimate the level of involvement of participants: How many were 100% involved, how many 75%, etc. Also collect testimonials — quotes from participants that you can use to describe the experience, materials, and value of it all. These may come right after the workshop or many months from that time. Start a file that you can add to as the kudos come in. Another file should have suggestions for the next workshop, from you and from participants. Pay attention to these as you begin planning for the next program.

> *The most important people at the workshop are the participants, NOT the presenters. THEY will carry your message into new arenas that you can't penetrate alone. If you have your audience for a whole day or more, you know their names and something about their work situations and potential. Begin to build a relationship that fosters continued contact with your program.*

Questions for today and tomorrow. Develop an official evaluation form that covers:

1) response to and achievement of your goal and objectives (knowledge, attitudes, etc.)
2) utility of workshop materials
3) appropriateness of techniques
4 logistics and management
5 overall program quality

A form like this won't help improve the workshop that it evaluates, but it should provide ideas on how the next one can be better.

Open–ended questions are also valuable and give you information that a check sheet cannot. If your workshop technique is a major concern, start one item with "If I were the teacher..." and invite constructive criticism. Also try "three things I will use (remember) from this workshop are..." and "The workshop would be improved if ..." Don't use too many open items, because careful completion of them will cut into your workshop time too much (examples follow). Collect all evaluation forms before people leave. Mail returns don't work.

Don't forget to complete the official forms your workshop sponsor requires.

Follow-up

Promises to keep. If you had a sign–up sheet the time to send out materials in response to it is ASAP. Enclose a short form letter to thank the receiver for attending the workshop and remind of the request for materials. Have you opened mail and wondered, "Now, what in the world is THIS?" While you expect people to remember your wonderful workshop, there are other things going on in their lives. A reminder is appreciated and gives you an extra shot at meeting your workshop goals.

Credit where it's due. Also on the ASAP list, or at latest a week after the workshop, write to your staff and support team (administrators, college liaison) to thank them for all their help. The goodwill generated by a prompt and sincere thank you is remarkable.

Write a "personalized" form letter with the magic of word processing. Thank each person for attending, remind them of the excitement generated for the workshop topic, and suggest some additional things they might do in their own teaching situations to use what they learned. Suggest a coming conference that they might attend for further professional development and to see friends they met at the workshop.

If you want teachers to do innovative things, they need administrative support or at least acceptance. A workshop sponsor, or the college liaison or administrator, could write to each of the principals whose school was represented at the workshop. The letter should commend the school for having such fine representation (list teachers' names), and should encourage support of the teacher(s) as they use some of the workshop ideas. This provides a positive stroke for the teachers as well as some additional visibility for the program and possibly additional support in the future.

Reporting to sponsors. If you are working for an agency or special program that is supporting your workshop, you have a responsibility to report your results in a timely and complete manner. Follow the sponsor's guidelines and deadlines, and be sure to collect all the participant information the sponsor requires. The sponsor uses this to create additional contact opportunities and to evaluate the success of various outreach techniques. If you expect continued support from the sponsor, this feedback is essential. Your report should be a no-frills, official report using the information you collect as part of your own and the sponsor's evaluation.

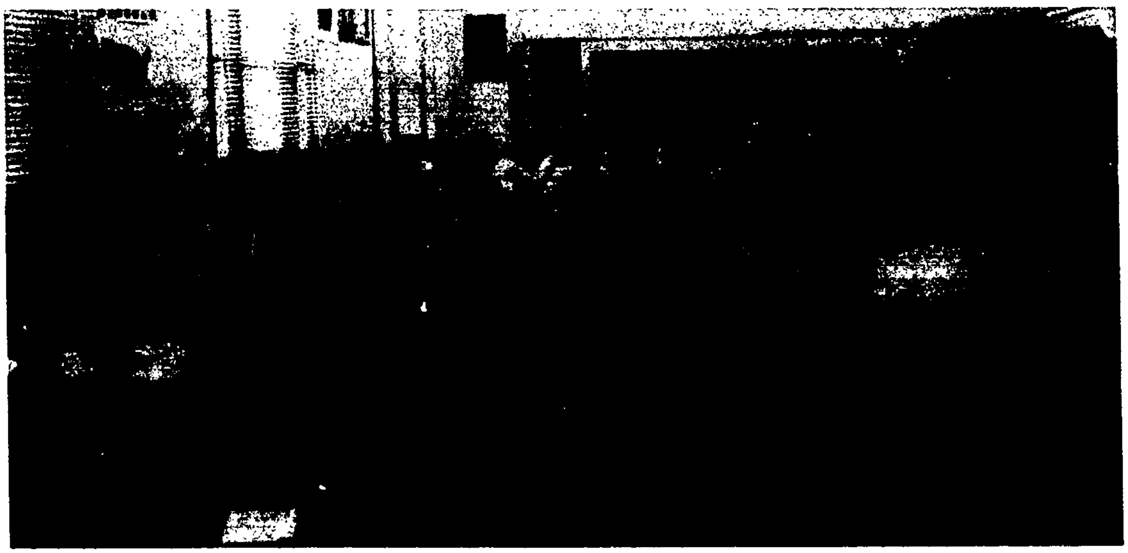
REFERENCES

Material for this guide was derived from many workshop experiences, especially those described in these references:

Fortner, R.W. 1986. Environmental education adoption potential of in-service workshop participants in developed vs. developing countries. In, J.E. Perkins (ed), *International Aspects of Environmental Education* (Monograph). Troy, OH: NAEE. pp. 2-24.

Mayer, V.J. and R.W. Fortner. 1987. Relative effectiveness of four modes of curriculum dissemination. *Journal of Environmental Education* 19(1):25-30.

Mayer, V.J. and R.W. Fortner. 1987. *The Ohio Sea Grant Education Program: Development, Implementation, Evaluation.* Columbus: The Ohio State University. 138 pp.



PLESE participants at the 1992 Eastern Center workshop completing an evaluation form.

How to Plan and Implement an Earth Systems Education Workshop

Following are suggestions for the development of short workshops. These were written by a group of participants the 1990 PLESE workshop based upon their experiences developing and conducting their own workshops during the year following their participation in the PLESE summer workshop in Columbus.

Do's

1. Plan! Plan! Plan! Make sure that you plan well in advance and as needed.

2. Select your date early — at least three months in advance.
   a. State meetings usually have their agendas set a year in advance.
   b. County or Regional meetings usually have theirs set up at least six months in advance.
   c. Have your University Liaison or Administrator assist you in setting up these meetings.

3. Set up planning sessions with your other team members to decide who will be doing what, who is to bring what materials, etc.

4. Target your aduience. At state and regional meetings, this may be difficult to do. However, once you have registered the participants for your own workshop, you can determine what their needs will be as far as activities, materials, etc.

5. Advertise your meeting at least one month in advance.
   a. Use a catchy title.
   b. Provide a good description of the workshop
   c. Set your registration deadline
   d. Contact those you know who would benefit from the meeting and who would be a good advocate of Earth Systems Education.
   e. Make an attractive brochure for your advertisement.

6. Consider door prizes, things that teachers would use and appreciate having. Contact publishers, local businesses, college liaison, etc.

7. Use various learning and teaching modes.

8. Class examples. If you have projects or work that your students have done, have them available for teachers to examine.

9. Use materials that are not expensive and that are easy to get.

10. Have two agendas prepared, one for the participants and a separate one for your team (this would be more detailed and specific as to time frames, responsibilities, special needs).

11. Always allow a question and answer period at the end of the workshop.

12. The administrator who supports your work should be present at the workshop.

13. For the longer workshops that you plan, refreshments should be available, possibly donuts and coffee/juice in the morning, and crackers/cheese or veggies and iced tea/coffee, etc. in the afternoon.

14. Resource Materials:
    a. Have enough copies of all handouts for everyone.
    b. Display resource books, posters, activities attractively. Information on how to obtain them must be available.

15. Start on time and end on time.

16. Use ice breaker at the beginning to get everyone comfortable. Keep a relaxed atmosphere.

17. Divide the group periodically into grade level teams, activity stations, building groups, etc.

18. Room arrangement should be accessible to everyone (handicapped), uncluttered, and comfortable (not too hot or cold). Use tables and chairs rather than desks.

19. Allow time for evaluation.

20. Try to set up workshop room at least 24 hours in advance so you are not under pressure at the last minute. Test all electrical equipment prior to the meeting (VCR, slide projector, TV, computers, tape recorders, software, etc). **Always have a plan B.**

SAMPLE SCHEDULE FOR A FULL-DAY WORKSHOP

8:00-8:30	Coffee (bring your own cup) donuts Icebreaker Activity: *Are You Me?* (Project Wild) Introduce one another (participants) Earth Systems Team Introduction
8:30-9:15	The NEED for Earth Systems Education/Curricular Reform 1. Aesthetic intro: slides/narrative (10 min) 2. Jane: (10) New State Requirements/Model Curriculum Reason teachers are present: to help revise county and local curriculum (STS-NSTA 2061/lack of Earth science) 3. Doris: (10) Project 2061: "Systems Approach" to curricular revisions
9:15-9:45	EARTH SYSTEMS MODEL Carol: 1. Seven Understandings for Earth Systems Education 2. Spheres Model 3. K–12 Approach 4. How the approach differs from traditional Earth science
9:45-10:00	BREAK — Challenge for the break: From your area or region, identify one example of each subsystem or find an item or opportunity to use for one of the Earth Systems Understandings
10:00	Debrief from break
10:15-11:15	Learning stations: 4 groups 9/ 15 minutes —hydrosphere —lithosphere —energy —biosphere
11:15-12:00	Technology Stations: —Kid's Network Telecommunications —Laser disc-Earth Science —Mineral computer program/mineral collection —Science Helper CD ROM

BRING YOUR OWN LUNCH: 12:00-12:30—Resource Table

12:45-1:30	Grade Level Meetings (EL, MS, HS) resources, lessons, discussion of what they are doing, etc.
1:30-2:00	BREAK
2:00-3:00	Whole Group Discussion —resources —sharing some projects in districts (Eisenhower, etc.) —what can team do: Tapestry grant, EE grants —any whole county projects —PARADIGM Tapes: future role/goal of ESE —evaluation
3:00	FINALE—RAIN FOREST RAP!

We probably have too much, but we can't stand it when they get bored and start wasting time. Work, work, work...

—Prepared by Nancy, Colin, and Jim; Summer 1991

8

Scoping Out an Earth Systems Curriculum

As teachers think about restructuring their curriculum to accommodate a more modern approach to science, many have found it helpful to see what other teachers, who have been thinking about such restructuring, have accomplished. In this and the next section we provide samples of such work and thinking. Normally the first effort at restructuring curricula is to think long range. What is it that the new program should accomplish in terms of content learned by the student and approaches used? Normally this results in a syllabus that then provides the guide to the development of activities to fit the syllabus. In this section we provide an example of how teachers have thought about restructuring their curricula at each of the three levels: elementary, middle school, and high school.

Elementary

The first article is one by Frank Day, and looks at an elementary restructuring effort using the Earth Systems approach. It is not a syllabus but a way of thinking about the development of a program. In 1994, the Leon County Schools (2757 W. Pensacola St., Tallahassee, FL 32304) published their *Elementary Science Curriculum Guide.* A team of teachers and an administrator from the county school system participated in the PLESE 1992 summer workshop in Columbus. As a result this curriculum guide is very heavily influenced by the Earth Systems Education model. For a complete elementary school guide, you might want to contact Joel Dawson at the Leon County School office for a copy of the guide. You will find it to be an excellent resource. Another very complete Earth Systems effort at the elementary level is the program developed by the Anchorage Alaska City School System. Entitled *The Earth Systems Program,* it is an effort to develop a syllabus and activities for a restructured K–6 science program. The program seeks to create a 'Sense of Wonder, Discovery, Balance, Belonging, Responsibility, and Place.' It has received federal funding for this effort. If interested you can contact Judith Reid or Emma Walton at the Anchorage City school office. Walton was the administrator member of the PLESE 1991 Alaskan team that participated in the Greeley workshop that summer. In Section Nine of this Guide you will find an actual Earth Systems unit developed by a husband and wife team who participated in the PLESE program, Carla and Bill Steele of Marysville, OH.

Middle School

As a result of the PLESE program and a follow–up middle school program in central Ohio funded by the Eisenhower program, there have been several school districts which have developed Earth Systems curricula at the middle school level. In this section we have included the draft syllabus developed for the Bexley, Ohio, Middle School. It was developed by the Bexley Middle School team, led by Dan Jax, who was also the co–director of the Eisenhower grant which funded the two year long program. The program involved teacher teams from ten central Ohio school districts. The team from the South–Western City Schools was led by Dave Crosby and the one from the Columbus City Schools by Shirley Brown. They collaborated to develop the middle school unit you will find in section nine.

High School

Finally, we have included an article from *The Science Teacher* which describes the development of the high school program in the Worthington, Ohio, City Schools. It integrates Earth Systems concepts and replaces the traditional Earth science and biology courses commonly taught in the ninth and tenth grades. An update of the curriculum along with samples of activities from the curriculum is included in Section Nine.

Earth Systematize

This is a description of the program developed by Frank Day, Webutuck Elementary science teacher, a participant in the 1991 Summer Workshop in Columbus. He has used the Earth Systems Understandings as a way of organizing his elementary science program.

An Innovative approach

Earth Systems Education was developed at Ohio State University under the direction of Dr. Victor Mayer. I adopted the Seven Understandings of Earth Systems Education into a plan called *Earth Systematize*. Using the Understandings, I began the task of applying Howard Gardner's theory of multiple intelligence to develop a holistic approach to science that would make science relevant to every student. Hoping to encourage the child not normally science oriented, I set out to add music, art, body movement, imagery, and poetry to my science classes.

Understanding #1 ***The Earth is unique, a planet of rare beauty and great value.*** This Understanding was incorporated into my Eco–Inquiry unit. Using examples of illuminist art from the Hudson Valley School of landscape painters, we incorporated landscape drawing into our examination of ecosystems study. The careful recording of detailed features was emphasized. The four spheres — hydrosphere, atmosphere, lithosphere, and biosphere — were also woven into Haiku poetry, used in Japan to express nature.

Understanding #2 ***Human Activities, collective and individual, affect Earth systems.*** This Understanding was incorporated into my Energy Unit. Students do a variety of hands–on activities to review present and future energy resources. Student activities range from creating wind turbines to cleaning up oil spills. The highlight of this unit is the acid rain dance drama. Students draw the sequence to the story of acid rain from the formation of ponds, buildings, and plants. In groups, they design body movements and costumes. The dance drama is divided into 5 acts. Act I students are ancient fern trees falling into a prehistoric swamp. In Act 2, a coal layer is formed and is mined. Act 3, takes place in the coal burning factory, where a black whirling sulfur dioxide cloud leaves the smokestack. Act 4, the sulfur dioxide mixes with a water vapor in a swirling dance that combines the two into an acid rain cloud. The final act has rain falling on students acting as choking fish, buildings with ruined finishes, and plants unable to absorb minerals from their roots. This drama has been done at workshops for teachers many times with much success.

Understanding #3 ***The development of scientific thinking and technology increase our ability to understand and utilize the Earth and space.*** Our students are taught fair testing with experimental groups and control groups; while testing class made fertilizers. In addition, we have been recording data and creating charts on the computer network at our school. Students draw diagrams of science topics using the IBM program, Linkway Live. We hope to be capturing pictures for our files in the future. Stereoscopes are used for viewing small objects such as mold. To assign values for new rating standards, numbers are assigned such as 0–10 or 0–5 for variations in color or amounts of mold coverage.

Understanding #4 ***The Earth is composed of the interacting subsystems of water, land, ice, air, and life.*** Exposure to the interaction of the sphere is accomplished by an integration of science and social studies through an exploration of biomes. By studying the effects of rain and temperature on various biomes, students help build this concept. They examine the relationship of living things with their environment by asking why conditions are perfect for a particular species. A biome folder is produced by each student.

Understanding #5 ***The Earth is more than 4 billion years old and its subsystems are constantly evolving.*** A unit, Time, is being planned. It will incorporate a geologic time line along our school nature trail. A student trail guide will identify each division. In conjunction with this, a comparison of how man has dated time for historical referencing will develop, and at the farther end of the scale, how time is recorded in light years for measuring the universe.

Understanding #6 ***The Earth is a subsystem of a solar system within a vast and ancient universe.*** *Decoding the Stars* was developed to fulfill this Understanding. By learning to read and write bar

codes, students were led to decoding spectral lines made by the elements. Using spectroscopes, they were able to decode the elements that made up various stars including the Sun. They also learned the relationship of color, temperature, and spectral classes. Students learned how the Greek alphabet is used to show apparent brightness of stars and chose a constellation to draw and research the Greek myth associated with it. Using a 30 ft. representation of the Sun's spectral line, students performed a dramatic presentation called the Solar Spectacular. Students played sunlight passing through a prism and breaking up into the wavelength represented by the lines. A parents night was held to present the drama. Also held, were Big Dipper races, with students racing along bases representing the stars of the dipper and shouting out the name of each star as they passed it. The evening was completed with night sky viewing. A local astronomy group came with a variety of telescopes for a tour of the sky.

An activity on moon mapping was presented at Harvard Smithsonian Project SPICA, and is being refined for presentations. It will focus on the use of longitude and latitude lines in plotting features of a globe. Students use the lines to place craters on the surface of a blank globe. They also plot the landing sites of the astronauts. This program will be adaptable to other planets and their satellites. Our students are also field testing the Harvard Smithsonian Project ARIES unit Astronomy. It focuses on the use of a light box to show how the seasons occur and the angle of sunlight striking the Earth.

Understanding #7 ***There are many people with careers that involve the Earth.*** Although careers are mentioned in every science unit, the force of the Engineering unit centers on the task of problem solving within specific guidelines and limitations. Students explore various materials and use them for various constructions. Students can be given tasks such as creating certain sounds or making unusual musical instruments. Students also are given an object like a wooden donut and create an original invention from it. Students are encouraged to use recycled materials in the production of this invention. Materials are limited by rules of safety and students are asked to have parents assist with any tools needed. Flight engineering is explored. Students create paper models to explore the forces at work during flight. Students create their own design and fly their creation on flight day. Distance and accuracy are measured, to determine the flight performance. Students also attend IBM Engineering Day held each year to watch demonstrations of the latest engineering break throughs.

During the twenty–five years of watching elementary science change from text to hands–on science, it seems that a holistic approach such as Earth Systematizing and Howard Gardner's multiple intelligence theory are needed. Tailoring to student talents is the goal. Using innovative teaching strategies will foster a lifelong interest in science.

Bexley Middle School Science Curriculum

The following curriculum guide is still in its developmental stages. It is the product of one of the central Ohio Middle School Earth Systems Education teams. The team is led by Dan Jax, eighth grade teacher in Bexley. It is provide here to assist other middle school teachers with ideas as to how an Earth Systems syllabus might look.

Introduction

The science curriculum at the middle school level must reflect the needs and nature of middle school students. Adolescents are constantly striving to figure out who they are and how they fit into the larger society. They are accustomed to daily changes in all aspects of their lives. Schools and curriculum are an important part of this change. Not only are the students themselves changing dramatically, but society itself is experiencing, thanks in part to developing technology, tremendous change.

The science curriculum needs to address these changes. The science curriculum at Bexley Middle School does this in a variety of ways. The content of the curriculum includes topics that are at the forefront of scientific endeavor and are some of the most important issues of the day at the local, regional, and global levels. For instance, we study such local issues as the changing Metro Parks and the human impact on them, how acid rain affects Bexley, and how humans have altered the local watershed.

Other topics include, but are not restricted to, global climate change, rainforest destruction, solid waste management, wetland destruction, and ozone depletion. The curriculum is designed to be flexible in order to respond to and incorporate current events and changes in curriculum guidelines at the local, state, and national levels. Our curriculum agrees philosophically with such national curriculum development projects as Project 2061 (American Association for the Advancement of Science), Scope, Sequence, and Coordination (National Science Teachers Association), and Earth Systems Education (The Ohio State University). It also ties in very well with the emerging state standards for science education.

Middle school students, just like all people, experience the world around them in a wholistic, integrated way. The separate science disciplines have increasingly artificial boundaries. In order for all people to have a full, complete understanding of the world around them science needs to be taught in an integrated fashion. When students study the ecosystems at Blacklick Metro Park, for example, they need to see how the biological, geological, meteorological, and physical aspects of the environment all interact and are dependent upon each other. It is also essential for students to realize the role that humans play in the interactions, that they are an important part of them, and they are able to do things to affect the interactions.

The science curriculum at Bexley Middle School revolves around an Earth Systems approach that has been developed over the last several years through several projects at the Ohio State University. Earth Systems is a wholistic, integrated approach to the teaching and learning of science that uses the Earth as the context. The Earth is composed of the varied systems of air, water, land, life, and ice. These systems do not exist independently, but interact in a variety of ways. It is the interactions among these systems and the human impact on these interactions that we focus on in the science curriculum at Bexley Middle School.

Social science research is making it increasingly apparent that learning for middle school students is at least partly socially–derived. Students need to work with their peers to be able to develop a fuller understanding of the world around them. Students need to have control over what they are learning. When students are provided with the opportunities to construct their own knowledge then learning will be truly meaningful and will last. To foster this we use cooperative learning techniques, including group projects, the sharing of information with others here at Bexley Middle School, with other schools in central Ohio, and with large and small group field trips to several central Ohio locations.

More and more information is available through a variety of technologies, including videodisc, CD–ROM, on–line databases, and electronic networking. It is our goal that students have as much access to these sources as possible and to develop the skills necessary to use them effectively. This is a goal for life–long learning.

An Earth Systems approach requires a type of evaluation of student progress different than the traditional objective test. Assessment of students includes presentations of individual and group projects, open–ended individual essay–type tests, using scoring rubrics, the evaluation of student conceptions and pre–conceptions with concept maps and other methods, and the building of a portfolio with authentic work kept in printed and video formats. The goal of learning and teaching is for the curriculum to become more student–directed and less teacher–directed over time. Assessment, then, is necessarily very performance–based.

State of Ohio Science Curriculum Standards

The State of Ohio has developed state standards of science education that are embodied in three major categories of concepts: Goals and Outcomes, Strands, and Themes. These are intended to guide the development of the science curriculum in each district in the state of Ohio. They are:

Goals and Outcomes

Goal 1 — The Nature of Science.

To enable students to understand and engage in scientific inquiry; to develop positive attitudes toward the scientific enterprise; and to make decisions that are evidence–based and reflect a thorough understanding of the interrelationships among science, technology, and society.

Goal 2 — The Physical Setting.
To enable students to describe the relationship between the physical universe and the living environment; and to reflect upon and be able to apply the principles on which the physical universe seems to run.

Goal 3 — The Living Environment.
To enable students to describe the relationship between the structure and functions of organisms; to assess how organisms interact with one another and the physical setting; and to make decisions that ensure a sustainable environment.

Goal 4 — Societal Perspectives.
To enable students to analyze the interactions of science, technology and society in the past, present, and future.

Goal 5 — Thematic Ideas.
To enable students to use major scientific ideas to explore phenomena, inform their decisions, resolve issues, and solve problems; and to explain how things work.

STRANDS

Strand 1 — Scientific Inquiry.
To include modes of inquiry (processes of science), habits of mind (problem solving, ethics), and attitudes and dispositions (curiosity, creativity, inventiveness).

Strand 2 — Scientific Knowledge.
To include the wholistic nature of the world (integration), how knowledge is ..ined, and the structure of knowledge.

Strand 3 — Conditions for Learning — Constructivist Approach.
To include giving students time to construct knowledge, using diverse instructional and assessment strategies (including performance–based), using a collaborative setting in which groups and individuals are accountable.

Srand 4 — Applications.
To use real–life, age–appropriate experiences for students to develop knowledge and skills, and to develop the scientific literacy necessary to cope with and understand the world around us.

THEMES

1. Energy
2. Systems
3. Patterns
4. Change through Time
5. Scientific Models

BEXLEY MIDDLE SCHOOL SCIENCE CURRICULUM GOALS

The goals of the Bexley Middle School science curriculum include outcomes for students, methodologies for instruction, and philosophies of science and the approaches to teaching it. How these are related to the three areas described in the state standards are indicated by the abbreviations at the end of each goal. G3 indicates State Goal 3, S2 is State Strand 2, etc.

1. To develop life skills for a democratic society in an increasingly technological world.

2. To integrate life, Earth, and the physical sciences in an Earth Systems approach. Earth Systems is based on seven essential understandings that students should have as a result of an Earth Systems course. To further integrate the related and appropriate areas of social studies, language arts, mathematics, health, and integrated studies as defined at Bexley Middle School.

3. To use current technology, computer work stations, CD–ROM videodisc, and on–line databases to access and deal with information, and to network with students and teachers in other school districts to share that information.

4. To focus on the local environment with global implications. To see how all aspects of environments at the local through global levels have changed over time. Students will explore the part that humans have played in the environmental change.

5. To use field experiences with both large and small groups. Areas include, but are not restricted to, several Metro Parks, Alum Creek, and local environmental businesses and agencies.

6. To have students actively engaged in doing science. To have students do science in a variety of ways and to see that there are many approaches to doing science. Students will know that there often is more than one solution to a problem and all people, including scientists, make decisions based upon the best available information but that decisions and ideas can change over time as the available information changes.

7. To use non–traditional assessment. To determine student pre–conceptions using concept maps and other methods and for students to deal with any misconceptions they may have about the topic at hand. Evaluation is based on student performance, on individual and group work on a daily basis, and on long–term projects.

8. To involve the community as much as possible, including mentoring, using business people to make presentations to classes, and to have parents serve on panels in class.

9. To use resources other than a textbook. An Earth Systems approach that is locally focused precludes relying on a textbook series to deliver the curriculum. Instead, we use several sources of materials including such national curriculum projects as Project Wild, CEPUP, many different resource books and magazines, videotapes, videodisc, CD–ROM, on–line databases and local sources like governmental agencies, environmental businesses, and parents.

10. To be issue–oriented. Issues will include, but not be restricted to local lawn care practices and their effect on the environment, human impact on the local watershed, implications of water and energy use in central Ohio, populations of humans and other organisms, human "control" of nature, global change, and rainforest and wetland destruction.

Science Process, Scope, and Sequence

The scope and sequence of the middle school science curriculum is a philosophical framework for the approach to be used in planning the experiences that students will have in the seventh and eighth grade. The framework includes those processes that we feel are essential for middle school students to use in any science course. The sequence implies that the processes will be developed over time and that some will become more emphasized as students move into the eighth grade. The framework also includes some of the important philosophical underpinnings of the program and how they change over time. None of the things in the framework will be totally excluded from either grade level.

Grade 7	Grade 8
More of a local/ regional focus	More of a regional/ global focus
More concrete	More abstract
More teacher–directed	More student–directed

Increasing student responsibility

Communicating

Observing

Classifying

Understanding

Applying

Interpreting

Content Scope and Sequence

The content of the seventh and eighth grade science courses is given in approximate order. Major topics are used as headings. The specific things that students are expected to deal with are listed in question format beneath each topic. You will notice that there are things in the seventh grade curriculum that will be expanded upon in the eighth grade. It is our intention to articulate the seventh and eighth grade curricula as much as possible.

SEVENTH GRADE EARTH SYSTEMS SCIENCE

A. Ecosystems: What they are.

- What is included in the definition of an ecosystem?
- How do the seven understandings of Earth Systems Education help define an ecosystem?
- What are some of the major ecosystems found in Ohio?
- What are the biotic factors found in an ecosystem?
- What are the abiotic factors found in an ecosystem?
- How can the abiotic factors of an ecosystem be determined?
- How can the biotic factors of an ecosystem be observed?
- How does the water quality data we gather locally compare to data gathered by other schools in the Project Green network?
- How does sharing information with other schools relate to the process of scientific investigation?

B. Ecosystems: How they work.

- What are the major categories of organisms that make up an ecosystem?
- How are these organisms dependent on one another?
- What are the relationships among species, populations, and communities?
- How do organisms interact with one another?
- How do organisms interact with the nonliving environment?
- What is a food chain?
- What is a food web?
- What is an energy pyramid?
- How are water and minerals circulated through an ecosystem?
- What is the source of energy in an ecosystem?

C. Ecosystems: What keeps them the same? What makes them change?

- What is the predator–prey relationship?
- What is the host–parasite relationship?
- How do birth and death rates affect population dynamics?
- How does competition affect population dynamics?
- How do biotic and abiotic factors affect population dynamics?
- How does specialization (habitat and niche) help minimize competition among species?
- How does the computer simulation SimAnt model the population dynamics of a species?
- How does the computer modeling program STELLA help us to understand the complex relationships within an ecosystem?
- What are the different stages of succession?
- How does succession change the abiotic and biotic features of an ecosystem?
- What other factors might cause an ecosystem to change over time?

D. Human impact: Population growth.

- What has caused the dramatic increase in the world's population?
- How has Ohio's population changed over time?
- How do birth and death rates affect human populations?
- What other factors influence the dynamics of human populations?
- When did our shift to urban living occur?
- Why did we shift to urban living?
- What are the environmental consequences of urbanization?
- How has urbanization affected the quality of surface and ground water in the area?
- How has urbanization affected the soil of the area?
- How can we reduce the environmental impact of urban living?
- How can you make your own backyard environmentally friendly?
- How can we make our cities more sustainable?
- How does the computer simulation SimCity illustrate the effect of urbanization?

E. Human impact: Consumption of resources.

- What are renewable and nonrenewable resources?
- What are some examples of them?
- Where are these resources located?
- How are they formed?
- What resources are found in Ohio?
- How are these resources obtained?
- What are resources used for?
- How many items we use every day come from nonrenewable resources?

- How long can we reasonably expect our nonrenewable resources to last?
- How can we extend the supply of our resources?

F. Human impact: Pollution.

- How is our consumption of resources related to our solid waste?
- How much solid waste do each of us produce?
- What is in the solid waste stream (from individuals, Bexley, Franklin County)?
- How is the solid waste problem being investigated?
- How is solid waste being handled in Franklin County?
- How can we reclaim the resources in our solid waste?
- How is our consumption of resources contributing to air pollution?
- What types of air pollution are being generated?
- How are the different types of air pollution formed?
- What are the environmental consequences of air pollution? (global climate change, acid rain, ozone depletion)
- What can we do to reduce air pollution?
- What are the sources of water pollution in Bexley and the rest of Franklin County?
- How can we reduce the amount of water pollution coming from residential areas?
- What kinds of tests can be done to determine the quality of a body of water?
- How does sharing water quality data with participants in Project Green and the Central Ohio Earth Systems Education network help us to understand the water pollution problem?

G. Human impact: Reducing our impact.

- What can we do to reduce our impact on the Earth System?
- What policy changes might help reduce human impact?
- Why is stewardship important?
- How can the seven understandings help us better appreciate, protect, and sustainably use the Earth?

Eight Grade Earth Systems Science

A. Watersheds and Issues

- What is the urban watershed? (especially the Bexley part of it)
- How are humans individually a part of the urban watershed?
- How is the urban environment a contributor to the quality of surface waters?
- How do streams in Ohio flow?
- What is the major drainage divide in Ohio?
- How does human intervention in watersheds influence flooding?
- How is the drainage related to water quality? (detergents/phosphates)
- How can the water quality of portions of streams be monitored?
- How can computers help to manage and manipulate water quality data?
- How can electronic networks be used to disseminate information about the environment? (sepcifically, water quality)
- What can citizens do about deagraded water quality?

B. Wetlands

- Where are wetlands found? (interface/interactions)
- What functions do wetlands serve in the environment?
- What are some Ohio wetlands?
- What is the value (to humans) of wetlands?
- What is the biodiversity of wetlands?
- How can the nature of wetlands be determined? (field trip)
- What physical factors are an important part of wetlands?
- How can wetlands be simulated/managed on a computer? (STELLA)
- How are wetlands disappearing? (including legislation)

C. Biodiversity

- How can biodiversity be determined?
- What is the biodiversity of Bexley? (keep a journal)

- Why is the biodiversity of Bexley the way it is? (compared with other areas)
- Why is biodiversity important to humans?
- How has biodiversity changed over time?
- How can diverse organisms be modeled on a computer? (SimLife)
- How have humans affected biodiversity?
- How does deforestation affect biodiversity? (Ohio and globally)

D. The Earth—Change Through Time—Resources

- How are the locations of wetlands related to global climate?
- How has climate changed over time? (thousands to millions of years)
- How can proxy data (tree rings, coral banding, ice cores, glacial deposits) be used to tell us about climates in the past?
- Why have organisms changed over time? (millions to billions of years)
- What happens to biodiversity when the climate changes?
- How have humans affected climate change? (global warming)
- How has climate change affected human populations in the past?
- How does deforestation affect climate?
- How can the climates on Venus and Mars be used to help explain global climate change on Earth?
- How can a computer simulation help to explain how human activity affects the climate of planet Earth? (SimEarth)
- How do weather events affect populations?
- What causes these weather events?
- How can geological events affect climate? (volcanic eruptions)
- Why are volcanoes located where they are?

E. Ohio Natural Resources

- Plate tectonics - Where are global mineral resources located and why?
- What are the effects of extracting these resources?
- Do earthquakes occur in Ohio?
- What are the mineral resources of Ohio? (also fossil fuels)
- How did these resources form?
- How does the use of these resources affect the environment? (includes acid rain)
- What energy resources are available to replace fossil fuels?
- What factors affect the usefulness of the different types of resources? (central Ohio)
- What are the social/legislative ramifications of the use of these resources?

Appendix A — Earth Systems Understandings

Understanding #1

Earth is unique, a planet of rare beauty and great value.

Understanding #2

Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

Understanding #3

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

Understanding #4

The earth system is composed of the interacting subsystems of water, land, ice, air, and life.

Understanding # 5

Planet Earth is more than 4 billion years old and its subsystems are continually evolving.

Understanding #6

Earth is a small subsystem of a solar system within the vast and ancient Universe.

Understanding #7

There are many people with careers that involve study of the origin, processes, and evolution of Earth.

Appendix B — Resources (not all-inclusive)

Curriculum projects/printed materials

Project WILD, WILD Aquatic, and Learning Tree
Living, Lightly in the City, on the Planet,
CEPUP (Chemical Education for Public Understanding Program)

Periodicals

Garbage, National Geographic, Discover, E the Environmental Magazine, Earth, USA Today, Columbus Dispatch, Newsweek, Time, Scientific American, National Wildlife publications

Videodiscs

Our Environment, Planetary Manager, Optical Data "Windows" and Living Textbook series

Computer Software

SimCity, SimEarth, SimLife, SimAnt, various spreadsheet, word processing, database (HyperCard), communications programs

On-line Databases

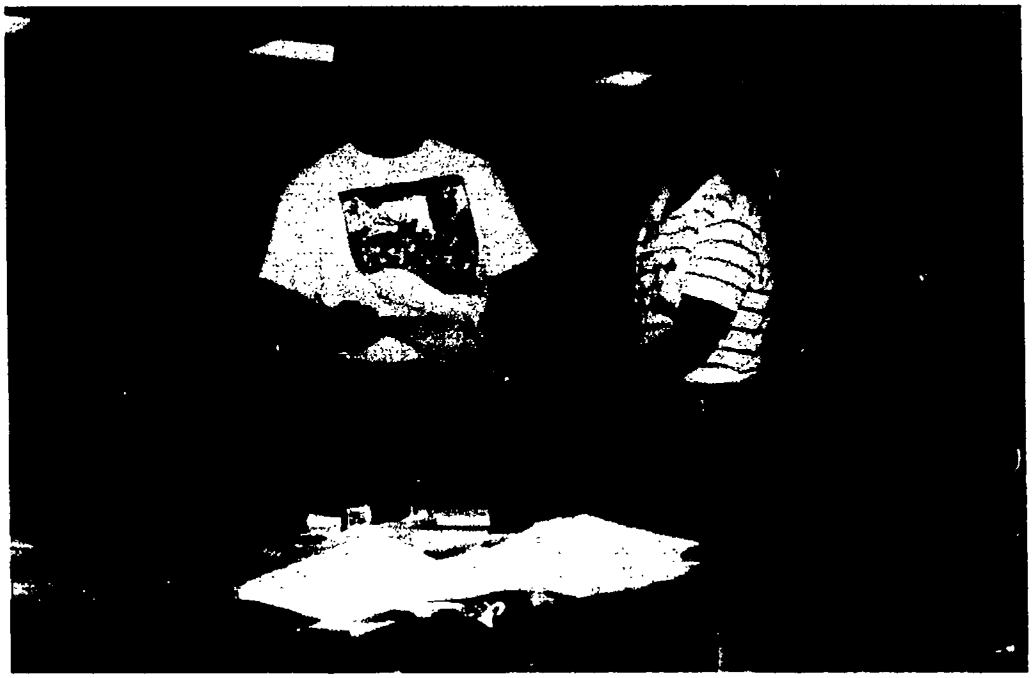
Prodigy, USGS Earthquake Line, SpaceLink (NASA)

Agencies

Ohio EPA, Ohio Department of Natural Resources, Franklin County Metro Parks

CD-ROM

Compton's Encyclopedia, JEI (University of Maryland), National Climate Data Center CDs, Audubon's Birds and Mammals, etc.



Dan Jax, leader of the Bexley Middle School Science team, discusses Bexley's ESE curricula with Hiroshi Shimono, head of the Earth Science Section of the Ministry of Education, Japan, Masakuzu Gotah, middle school teacher from Japan, and Salve Dorada, a high school teacher from the Philippines.

Biological & Earth Systems Science

A program for the future

The present curricula in science and mathematics are overstuffed and undernourished.... To turn this situation around will take determination, resources, and time.
—AAAS, Project 2061: Science for All Americans

by Rosanne Fortner, Roger Pinnicks, Edwin Shay, Pat Barron, Dan Jax, William Steele, and Vic Mayer

As far back as 1987, the high school science teachers of Worthington, Ohio, began to sense a need for change. Their dissatisfaction with the current curriculum grew as reports continued to rank U.S. students at the bottom of the global scale for achievement in Earth science and advanced biology. Only 3 percent of high school students enroll in Earth science; biology is the preferred starting course. And, as Project 2061 began to call for a "less is more" approach to science teaching, they were encumbered with a 1.35 kg Earth science text with a 550-word glossary and an even larger 1.5 kg biology text with a 900-word glossary. A system-wide self-assessment also identified other problems that included a lack of computer literacy technology access, real world linkages, and science career guidance. The impetus for change was in place.

TO TURN THIS SITUATION AROUND...

In response to the situation in their district, 10 science teachers, the department chair, and another teacher on special assignment collaborated to restructure the secondary science program. They sought to refocus lesson plans in the natural sciences, so that students would once again be learning about the structure and function of Earth systems—a focus all but abandoned in many secondary school programs.

WILL TAKE DETERMINATION,...

The efforts of the Worthington team were bolstered by statements of professionals on all levels. Project 2061 helped by identifying what every high school students should know. NSTA's Scope, Sequence, and Coordination echoed the need for change. At a conference sponsored by NSTA and the American Geological Institute, geoscientists, teachers, and science educators discussed the need for Earth science literacy. Ed Shay, a member of the Worthington team, participated in that meeting and came away feeling that the answer to his district's problems with ninth grade science was at hand.

The Worthington group refined a vision of Earth Systems Education that focused on how the subsystems of hydrosphere, atmosphere, lithosphere, biosphere, and cryosphere interact and relate to human activities. As a national curriculum model, Earth Systems Education provided a relevant context for teenagers.

Bringing about changes in curriculum structure, however, is not something to be taken lightly. Years of experience with the same curriculum generate a degree of comfort and confidence in teachers. To convince teachers to abandon their ways and strike out into the unknown is not a task for the faint of heart.

The Worthington team embraced the need to restructure, and vowed to make change happen. The course they designed

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integrated the ninth and tenth grade program into a new curriculum, Biological and Earth Systems Science (BESS), which offered:

- relevance to student needs;
- interdisciplinary and collaborative experiences (the way real science operates);
- understandings (rather than bits and pieces);
- rigor (exploring, questioning, and making decisions); and
- critical thinking (not just memorizing).

The team was so committed to their product that they encouraged the administration to make the new two-year sequence a *requirement* for all students. BESS I was taught in 1990–91, and BESS II for the first time in 1991–92. (The learner outcomes of the course are listed in Figure 1.)

RESOURCES,...

To start up a new program such as BESS, the team needed money, equipment, materials, and most of all, time. Once the weighty textbooks were abandoned, teachers had to find appropriate reading and lab materials. A new mindset had to be adopted, as well, as the boundaries between traditional subject matter and categories were softened and connections were emphasized.

The staff worked with the Ohio State University faculty in seeking out grants and materials for the BESS program. To broaden their own horizons, individual BESS teachers participated in the JEdi development project, the Sea Education Association Satellites in Education Conference, a conference on alternative assessment methods, and NSTA, NABT, and GSA conventions. The most valuable resource, however, was the creativity and resourcefulness of the teachers and their advisory groups.

LEADERSHIP,...

Little of the progress in BESS to date would have been possible without the commitment of those on the front lines of reform, the teachers themselves. They had a sense of mission, and theirs was truly a cooperative learning experience. A national advisory board was chaired by teacher Dan Jax from a nearby school system. Stanford professor Paul DeHart Hurd brought a national perspective, and provided the leadership that was needed when opposition surfaced. Some of the key objections raised by the "status quo" included:

- parents of talented students who wanted a one-year fast track to A.P. courses.
- Guidance counselors and parents, who feared that the course name on a transcript would be misunderstood by colleges. (The term Biological was added to the course name as a result of counselor input.)

It is fortunate that the many types of

FIGURE 1. Learner outcomes.

As a caring, responsible, and scientifically literate person, I can...

1. Exhibit a holistic understanding of planet Earth, recognizing that it is a system comprised of changing and interacting subsystems.
2. Demonstrate an aesthetic appreciation of, and respect for, the beauty and value of the Earth, its grand cycles, and its life.
3. Exhibit a holistic understanding of individual organisms, recognizing that each is a system comprised of changing and interacting subsystems, and that each is also a part of environmental processes.
4. Demonstrate an awareness that humans are unique, that our activities may seriously impact planet Earth, and that individually and collectively we have the responsibility to make informed decisions on issues affecting the future of our planet and its inhabitants.
5. Demonstrate wise use of Earth's limited resources.
6. Use current technologies (computers, remote sensing, laboratory instrumentation, etc.) as tools to access and process information.
7. Access, sort, interpret, analyze, evaluate, and apply information from a wide variety of sources, both current and historic.
8. Recognize and define problems and issues, and demonstrate skills useful in solving problems and analyzing issues.
9. Demonstrate skills for engaging in individual and collaborative scientific and social endeavors.
10. Demonstrate effective communication skills within the context of science.
11. Show understanding of the basic concepts and principles of science, and apply them (along with the processes of science and technology), to solve problems, make decisions, and understand the world.
12. Recognize biased information, pseudoscience, and fact versus opinion.
13. Take and justify positions on science-related issues, based on valid, rational science concepts and ethical values.
14. Demonstrate an awareness and appreciation of the personal usefulness of science as a way of learning about how the world works.
15. Demonstrate awareness of science-related skills, careers, and avocations.

leaders in the program maintained the determination to make it work.

...AND TIME.

More time than anyone could have imagined was spent developing curriculum while curriculum was in progress, planning day-by-day, securing materials and assistance. Physics teacher Faulke Palmer served as director managing fiscal aspects; Ed Shay and biology teacher Roger Pinnicks developed the broad master strokes on integrative topics, and special assignment teacher Pat Barron facilitated the process. Pinnicks and Jim Immelt were released from all teaching for the critical second year of planning, facing not only a new curriculum but a new set of parents and a new superintendent. No one said it would be easy, but all are convinced it is worth the effort.

Program evaluation is in progress to gauge the success of the BESS program in meeting its goals. Like all other aspects of the effort, this is a multifaceted challenge. The current instruments used to identify merit scholars are not likely to be the same ones that can assess collaborative skills, choice of technological applications, thinking and application ability, and knowledge of information resources, not to mention critical consumption of science information and recognition of the limitations of science.

For now, several forms of evaluation are in progress, assessing BESS students' performance in achieving the major goals of the course as well as mastering worthy portions of the more traditional science content. In general, student attitudes toward their science experiences are very positive in comparison with those in traditional courses prior to BESS and in other schools. The academically talented students have difficulty with the new operating modes and evaluation methods that do not rely on traditional testing. This portends a challenge for all curriculum restructure efforts. As Paul Hurd has said, "Everyone is in favor of progress but no one wants to change!" As we look harder at what real learning consists of, we must look equally hard at how to measure successful teaching. The ultimate goals of BESS are expressed as learner outcomes that transcend science disciplinary goals, and as evaluation of the program proceeds, the richness of data measuring those outcomes will add new dimensions to our understanding of success in science teaching and learning.

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NOTE
For additional information on BESS, please contact Rosanne Fortner at the address provided or BESS program leader Brian Luthy at Thomas Worthington High School, Worthington, OH 43085.

FIGURE 2. Year one framework.

A. WHAT IS A SPECIES?

Topic: Species and Populations

A1. What is a species?
A2. How and why do scientists classify things?
A3. What is species diversity and why is it important?
A4. How are changes in populations caused by nature?
A5. How do humans bring about population changes in other organisms?
A6. How is it possible that you can influence the possible extinction of species, including humans?
A7. What are the consequences of continued population growth?

B. WHERE IN THE WORLD ARE WE?

Topic: Change and Remote Sensing

B1. How are maps, aerial photos, and satellite images used to study the Worthington area?
B2. How do comparisons of data/information over time show change?
B3. How do ground observations provide clues for the interpretation of aerial photos and satellite images?

C. WHAT CAUSES WEATHER CHANGES?

Topic: Weather Systems

C1. What is the source of energy in our atmosphere?
C2. What causes weather to change?
C3. What are the interactions between large bodies of water, land, and atmosphere that influence weather?
C4. What makes the wind?
C5. What makes it rain or snow?
C6. How can changes in the weather be monitored and predicted?
C7. What causes seasonal changes in the weather?
C8. How does weather affect you, and how does it affect other organisms?
C9. What causes violent weather such as blizzards, tornados, thunderstorms, and hurricanes?
C10. How can you protect yourself in a blizzard, a tornado, or a thunderstorm?

D. WHAT FACTORS INFLUENCE ECOSYSTEMS?

Topic: Ecosystems

D1. How did the landforms and soils in this area develop?
D2. How did the bodies of water and landforms influence organism distribution?
D3. How do we make use of these natural features today?
D4. How does energy flow within an ecosystem?
D5. What are some interrelationships in an ecosystem?
D6. How are ecosystem relationships altered and what are some of the results of these changes?
D7. What are the factors that make up our deciduous forest biome?
D8. What factors could alter our deciduous forest biome?
D9. What are the factors that make terrestrial and aquatic biomes in the world unique?
D10. What effects do biomes have on global environments?

E. HOW IS AN INDIVIDUAL ORGANISM A PRODUCT OF ITS ENVIRONMENT?

Topic: The Individual Organism and Its Environment

E1. How is structure related to function in complex organisms?
E2. How does design (structure) influence the way organisms behave?
E3. How does the environment help to influence the design and/or behavior of an organism?
E4. What are some of the positive and negative ways that organisms respond externally to factors in their environment?
E5. How is an individual organism a product of what it takes in?

F. WHAT ARE THE LOCAL AND REGIONAL NATURAL RESOURCES THAT WE USE, AND HOW DOES THEIR USE IMPACT THE EARTH SYSTEM?

Topic: Ohio's Natural Resources

F1. What are Ohio's major natural resources, how did they form, and how do we use them?
F2. Which of these Ohio natural resources are renewable? Which are non-renewable?
F3. What are some of the consequences of obtaining and/or using these resources?
F4. How can we minimize the effects of the resulting wastes on the environment?

G. CULMINATING ACTIVITY

FIGURE 3. Year two framework.

H. WHAT IS A SYSTEM? A SUBSYSTEM?
Topic: Systems Concept (revisited)

I. HOW DO INDIVIDUAL ORGANISMS FUNCTION AND CHANGE THROUGH TIME?
Topic: Organisms as Systems: Structure and Function of Individual Organisms
I1. What is the internal structural organization of organisms?
I2. How do the internal subsystems of an organism function and respond to change?
I3. What are the main biochemical processes that sustain organisms?
I4. What structures and biochemical processes are related to reproduction?
I5. How do the structures and biochemical processes of organisms function interconnectedly to achieve essential matter and energy exchanges?
I6. What are some of factors that may change the normal functions of an organism's subsystems?
I7. What are some issues or concerns regarding the well-being of individual organisms?
I8. What makes life unique, valuable, and beautiful?

J. HOW AND WHY DO THE EARTH'S SUBSYSTEMS CHANGE AND INTERACT THROUGH TIME?
Topics: Changes and Interactions: Crustal/Ocean Evolution, Ecological Succession, and Climate Change
J1. What are the causes and effects of crustal evolution and other major changes in the Earth's subsystems?
J2. How does matter move through biogeochemical cycles involving different subsystems?
J3. What can fossils and other Earth archives tell us about the nature of and the rate of changes and interaction in the Earth's subsystems?
J4. How can changes in the Earth's subsystems be monitored and predicted?
J5. How and why are humans altering the Earth's subsystems?
J6. What are some issues or concerns raised from these activities?
J7. What should we do to minimize our negative impacts or changes in the Earth's subsystems?

K. HOW AND WHY DO SPECIES CHANGE THROUGH TIME?
Topics: Organic Evolution, Reproduction, Genetics, and Biotechnology
K1. How do the major natural processes that may result in changes in species work?
K2. What changes in genetic diversity may result from these processes?
K3. What evidence is there for organic evolution?
K4. How are genetic information molecules replicated, transmitted, expressed, and altered?
K5. What are the mechanisms and principles of genetics/heredity?
K6. How and why are humans altering natural genetic and/or reproductive processes?
K7. What are some potential implications and impacts of these alterations?
K8. What are some issues or concerns raised by these alterations?

L. HOW SHOULD WE MANAGE EARTH'S LIMITED NATURAL RESOURCES AND REDUCE NEGATIVE IMPACTS ON GLOBAL ENVIRONMENTS?
Topic: Earth's Limited Natural Resources
L1. What and where are Earth's limited natural resources, how were they formed, and why are they important?
L2. What are some issues or concerns regarding Earth's natural resources?
L3. What is the relationship between human population growth and the implications of managing Earth's natural resources?
L4. What are the responsibilities of humans toward natural resources?
L5. How can/should renewable resources be managed for sustainability?
L6. What are some organizations that are involved in environmental stewardship activities?
L7. What are some options available in the acquisition and utilization of natural resources that would minimize negative impacts on Earth's subsystems?

M. HOW SHOULD WE MANAGE WASTES AND POLLUTANTS AND REDUCE NEGATIVE IMPACTS ON GLOBAL ENVIRONMENTS?
Topic: Wastes and Pollutants
M1. Which major pollutant sources are not the result of human activities, and cannot or should not be managed?
M2. What are some issues or concerns regarding wastes and pollutants?
M3. How can wastes and pollutants that enter one Earth subsystem affect other Earth subsystems?
M4. What is the relationship between human population growth and the magnitude of waste and pollutant problems?
M5. How should we manage human-activities-generated wastes and pollutants and reduce negative impact on global environments?

N. CULMINATING ACTIVITY

INSIDE A BESS CLASSROOM

If you were to walk into a BESS classroom, how would this integrated program be different from a typical high school biology or Earth science class?

FACILITIES

Teacher Brian Luthy's room is typical of a BESS classroom. Its walls are covered with student generated computer art and collages illustrating interrelationships between various science topics. There are terraria and aquaria, rocks and minerals, and many maps and aerial photos in different formats on display. A magazine rack holds a variety of current science magazines. The classroom also contains six Macintoshes with large color monitors. One Mac has a modem attached to the phone line in the preparation room, and another is linked temporarily to the videodisc player. An IBM and CD-ROM workstation is carted between rooms as needed.

SCHEDULE

The class period is 55 minutes long, and BESS teachers have five classes per day. Teachers share a release day once a month, during which they exchange ideas and activities. Since computer hardware is somewhat limited, teachers alternate activities within the scope of a single science investigation. For instance, while one teacher has the computers for simulations or database development, another teacher does field work or uses mapping exercises to complement the computer applications.

SYLLABUS

The framework for BESS I and II is based on questions to be explored (see inset). It is a fluid structure for the curriculum, capable of being rearranged or otherwise altered in response to external events (teachable moments that can not be ignored, or internal opportunities such as teacher expertise and student interest).

A look at the types of questions used to structure the BESS curriculum makes it clear that this is not simply a course that does Earth science today and biology tomorrow. Topics suggested by the questions are integrated to a far greater extent, and frequently involve the use of innovative data sources. The questions are designed to address components of the Framework for Earth Systems Education (Figure 3), a way of thinking about science content that can quickly demonstrate the idea that "less is more." To fully develop one of the Earth systems understandings takes thought, innovation, use of diverse forms of historical and experimental data, and interaction of people with different approaches to problem-solving. Not only the content of the course, but the methods are different.

TEACHING METHODS

Lectures are rare, but 10-minute orientation programs may be used to introduce a new topic or laboratory approach. Visual aids come from videodiscs and CDs, and reading materials are drawn from daily newspapers and other periodicals. The main purpose in "teaching" is to set up a scenario for an investigation or establish a collaborative learning framework for a new topic.

Students work as teams about 75 percent of the time, alternately learning material from up-to-date sources and teaching it to other groups by integrating it with information they have collected. Serious discussions of science process, data interpretation, social ramifications of science, and so forth, are carried on in groups and may be brought to the entire class for amplification.

GRADING

Students are learning in nontraditional modes, and performance evaluation is adapted to those modes. Group activities are judged on the basis of a grading rubric that incorporates the objectives for the study as well as group process skills. Authentic assessments provide scenarios that require students to apply knowledge to new situations. For example, what must be known, and how can the information be obtained, to decide whether an extirpated species (river otters) could be successfully reintroduced to the local environment? Given certain data about river otter natural history and local development, students predict the outcome of reintroductions at various sites along the river.

SOME SPECIFIC EXAMPLES OF BESS ACTIVITIES

Endangered and threatened species are just a part of the important topic of biological diversity and its importance for a shared planet. Instead of doing encyclopedia research on various species, cooperative groups selected species to study for the purpose of protecting them. Their task was to find current relevant information on their species and threats to its survival, and present a proposal for how a grant of $5 million could be used in species preservation.

SimCity, a Maxis software program, is used extensively in BESS I for its capability to simulate land use planning and evaluation of alternatives in municipal development. When student groups are familiar with the way the simulation operates, they are challenged to develop the most polluted city possible. Since they know what combinations of housing, commercial, and industrial development create problems for the Sims, they can easily maximize the problems. The next challenge is to take a given amount of city funds and develop programs that rescue SimCity and restore ecological and social tranquility to their representative Earth systems.

Students at one high school studied a river that flows near their school. Collecting data from the river and its banks, using published scientific literature, aerial photos, and topographic maps, they assessed the feasibility of reintroducing the river otter to the area. Students then had to make recommendations to the head of the Ohio Department of Natural Resources on whether to reintroduce the otter or not.

DECEMBER 1992 ■

9

Sample Activities and Units

In this final section of the Resource Guide, we provide you with some sample activities that have been collected and modified by Earth Systems teachers to fit an ESE curriculum. We have provided them at each of the three levels. The Elementary unit was developed by a husband and wife team. Bill Steele was one of the PLESE staff members while he was working on his MS degree at OSU. When he returned to his position in the Marysville Middle School, he interested Carla, his wife, in the ESE effort. She participated in the final PLESE workshop held in Greeley in 1993. Subsequently they worked as a team to pull together ideas from the elementary team participating in the workshop to provide an integrated unit of activities.

The middle school unit was developed by Dave Crosby, a teacher at Park Street Middle School in the South-Western City School System (OH) and Shirley Brown, teacher at the Clinton Middle School in Columbus (OH). Dave was a team leader for the Middle School team at the 1993 workshop. The unit represents a synthesis of the ideas from this group and others that Shirley and Dave had developed by themselves and from other middle school teachers who participated in a middle school Eisenhower program conducted through The Ohio State University. The high school activities are some that are chosen from the Worthington Biological and Earth Systems Science Curriculum. They were edited by Mark Maley from activities he and his colleagues in Worthington had developed for their program.

Earth Systems Education Elementary Level Unit

Assembled and developed by Carla and Bill Steele, Marysville Village Exempted School District (OH)

Introduction to the Unit

The following is a collection of K–5 ESE materials than can be used as a unit or as separate activities. Any can be modified to work successfully within any of the elementary years. While all of the materials represent ESE philosophy, they also focus more specifically on the concept of change.

Change is inevitable. All things, living or not, change. Sometimes it is quite evident, such as the eruption of a volcano or the birth of an animal. Other times change is quite difficult to perceive on a human time scale, such as the growth of a giant redwood or the uplift of a mountain range. The materials which follow include examples of both rapid and slow change. Some are beneficial to life, some are harmful and some are neither. As long as the universe exists there will be change.

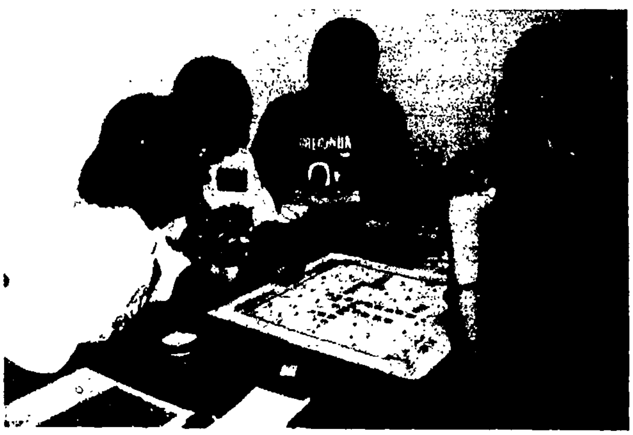
In each of the Earth's "spheres" or subsystems — Life (biosphere), Rock (lithosphere), Water (hydrosphere), and Air (atmosphere) — we can observe changes that take place both quickly and slowly. In the Life segment of this unit the life cycle of an insect allows students to observe how rapidly change can take place. The development of soil as illustrated in the Rock unit should provide insight into the very slow processes on Earth that cause equally important changes. Water, that invaluable and often unappreciated liquid, is the focus of a group of activities that provide both a better understanding of water and demonstrate the need to promote the stewardship of this resource. Again the theme of change can be seen as water is transformed from pure to polluted and back. The sometimes rapid and potentially violent changes that occur in weather patterns are examined in the activity on Air.

Seldom if ever do changes occur within one subsystem without affecting the others. These interactions make it imperative for students to attain a global perspective regarding their actions and those of our society and their impact on our land, life, water or air. Such changes influence the Earth systems in our Hemisphere and worldwide. These interrelationships are what make science both

interesting and challenging for many researchers both young and old.

A Native American perspective is taken in both the Rock and Air sections. These two activities have been excerpted from the book *Keepers of the Earth*. This volume follows the Earth Systems philosophy to a great extent and adds a component of literature preceding the science activities it presents. A representative Native American myth introduces the ideas to be studied in each section.

While change is inevitable it is not always desirable. Change we would call growth and maturation in plants and animals is definitely inevitable and typically desirable. Change in the quality of air, water, and land over the past several decades in many parts of the world is neither inevitable nor desirable, but we face a daunting challenge in trying to correct the problem. One major step in this battle is the education of the youth who have a tremendous stake in providing a more habitable planet for all of us to live on. Earth Systems strategies will allow students to better comprehend the challenge and goal of maintaining this planet as the only home we have.



Chris Tonsmeir, Carla and Bill Steele and Margaret Sadeghpour–Kramer work on ESE activity for an elementary school curriculum during the 1993 PLESE workshop in Greeley, CO.

The activities included in this unit are:

1. Earth
2. Wind and Weather
3. DRIPS in the Right Direction.... Cleaning up Water
4. Insects

Activity One: Earth

Subsystem: Rock

Understandings:

Earth is unique, a planet of rare beauty and great value.

Human activities, collective and individual, conscious and inadvertent, seriously affect Earth systems.

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

Earth is more than 4 billion years old and its subsystems are continually evolving.

There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

Description:

Mythical stories with related activities explaining the rock cycle, weathering, erosion, and soil formation.

Estimated Time to Complete Activity:

One to several class periods depending upon how many of the segments you complete.

Questions, Materials & Procedures:

See reference in Section Eight entitled "Tunka-shila, Grandfather Rock" and "Old Man Coyote and the Rock" of *Keepers of the Earth* pp. 57-63.

Reference:

Caduto, Michael J. and Joseph Bruchac. 1989. *Keepers of the Earth* Golden, CO: Fulcrum, Inc.
This book and its companions are available from The National Science Teachers Association, many natural history stores, and museums.

ACTIVITY TWO: WIND AND WEATHER

Subsystem: Air

Understandings:
Earth is unique, a planet of rare beauty and great value.

Human activities, collective and individual, conscious and inadvertent, are seriously impacting Earth.

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

Earth is more than 4 billion years old and its subsystems are continually evolving.

There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

Description:
Mythical stories with related activities explaining why and how the wind blows, things moved by the wind, air pressure, and pollution.

Estimated Time to Complete Activity:
One to several class periods depending upon how many of the segments you complete.

Questions, Materials & Procedures:
Use Section Nine entitled "Gluscabi and the Wind Eagle" from *Keepers of the Earth*, pp. 67-75. See this section of Activity One above for availability.

ACTIVITY THREE: DRIPS IN THE RIGHT DIRECTION...CLEANING UP WATER

Subsystem: Water

Understandings:
Earth is unique, a planet of rare beauty and great value.

Human activities, collective and individual, conscious and inadvertent, are seriously impacting Earth.

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

Earth is more than 4 billion years old and its subsystems are continually evolving.

There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

Description:
DRIPS = Developing Responsibility In Providing Solutions:

The surface of planet Earth is comprised mostly of water. Even though the Earth's population continues to grow at alarming rates, our water supply does not. Pollution of our planet's water is one of the most crucial issues facing the global community today — one that we must all address. It is the intent of this set of activities to create an awareness of both the aesthetic value and the overall importance of water — thus creating an awareness of the need for conservation and preservation of this vital natural resource. The unit features a series of activities that assumes knowledge of the water cycle (however a brief review may be necessary) and integrates across curricular areas. The presentation of the activities encourages cooperative learning so it is important that classrooms be arranged in order to facilitate groups of three to four students working together.

Part 1. Water Knowledge and Attitudes

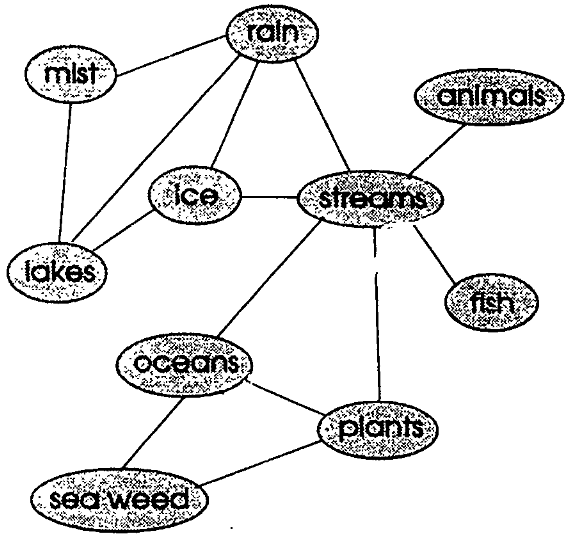
This initial activity sets the stage for the unit study by asking students to share the knowledge they already have about surface water, and encouraging them to make personal value judgments about the importance of water.

Completion Time: approximately 60 minutes

Materials Needed: Chart paper, markers, variety of pictures showing diversity in water forms (can be photographs, pictures from magazines, calendar art, etc., of lakes, streams, swamps, oceans, city reservoirs, water treatment plants, rain storms, and more), five tokens for each student (can be stickers or die cuts; each of the five tokens representing a differing viewpoint — ecological importance, monetary value, beauty, residential choice, least value).

Questions/Objectives:
What knowledge do students already possess about water — with specific regard to surface water (lakes, streams, rivers, wetlands, oceans, etc.)? What attitudes do students have regarding the importance and value of water?

Procedures:
Students will be divided into cooperative groups of three to four members. The teacher will ask all members to brainstorm what they already know about surface water to create group webs containing this information. Students may include any facts they feel pertinent to the topic such as types of surface water (streams, lakes, wetlands, etc.), pollution, causes for pollution, aesthetic characteristics of water, water activities, etc. One member from each group will serve as recorder to chart individual responses on the web. Allow five minutes for this portion of the activity and then ask for a reporter from each group to take turns sharing the information from each group web — one different fact offered by each reporter at a time. The teacher will record responses on a class web and facilitate this process until all responses have been reported. The class web will show what knowledge the students already have about this topic and will serve as a springboard for future investigations. The following



is just one example of how the class web could be organized — asking the students to classify "water" facts or information as responses are offered. The class web could be illustrated by students and should be added to as the unit study continues.

NOTE: This is but a sampling of the responses students may offer. Other topic headings could include water uses, water's influence on the arts, feelings inspired by water, water sounds, appearance of water (colors for example), storms, etc.

The teacher will then make available a variety of pictures representing a great diversity in surface water (see materials listing for Activity 1 for description). Have students display these pictures throughout the room. Each student will be given five tokens (stickers or die cuts). The teacher explains that each token represents a different viewpoint: ecological importance, monetary value, beauty, where someone would choose to live, and something of little value. Ask students to look at the pictures of water and explain to them that they will be asked to rate each picture according to what they deem to be of ecological importance, monetary value, beauty, where they would like to live, and the picture that represents the least value to them. After they have made these decisions, ask students to place the tokens accordingly. When all tokens have been placed, afford students the opportunity to explain and defend their decisions. The teacher should reinforce the idea that everyone's opinions and decisions need to be valued and respected. Differences reflect individuality, not whether someone is right or wrong.

Part 2. Water in Human Culture

"Water gives life to everything and is the bloodline of the Earth." This quote from Virginia Deswood–Ami, a Navajo participant in PLESE, is one that is mirrored by many cultures. Literature which embraces this perspective will be shared and discussed, giving students the opportunity to compare various cultural viewpoints with those of their own.

Completion Time: approximately 60 minutes

Materials Needed: literature…including fiction, nonfiction, poetry, folklore, picture books, etc…with special emphasis on multi-cultural selections...that deals with the significance of water and the part it plays in the cycle of life (suggested literature: Bringing the Rain to Kapiti Plain: A Nandi Tale, stories from Keepers of the Earth, poetry from Haiku: The Mood of Earth, Riverkeeper, selections from Earth Prayers From Around the World).

Questions/Objectives:
What part does water play in the cycle of life? How is the significance of water depicted in literature, especially in regard to various cultural viewpoints and beliefs?

Procedure:
Students should reassemble into their cooperative groups to share literature that focuses on the importance of water. Each group may choose the book, poem, etc. its members will study, from the selections made available by the teacher or through student preferences (see materials for Activity 2 for suggestions). Group members may decide how the literature selections will be conducted within each group: individual reading if multiple copies are available, book buddy sharing, a read–aloud by one member, etc. Following this sharing, each group will discuss the selection and have the reporter present it to the class. The teacher will then facilitate a discussion to aid students in understanding the importance of water in the cycle of life. This discussion should also serve as a way for students to compare their views, expressed in Activity 1, with those of people from other cultures and the perspectives offered in the various literature selections.

Part 3. Water Pollution

The central focus of the set of activities is introduced in this one: ways in which surface water can become polluted. Students will also begin to investigate how contaminants can be removed from water.

Completion Time: approximately 75 minutes or two class periods

Materials Needed: chart paper, markers, margarine tubs, water, salad oil, individual student journals, dish detergent, popcorn, spoons, salt, sugar, any other materials students suggest for cleaning the oil from the water.

Questions/Objectives:
How does water get dirty? How can water be cleaned once it is polluted? How does scientific literacy allow people to understand and manage water resources (what do we need to know to care for water)?

Procedure:
The teacher leads a discussion with the whole group dealing with the consequences that arise when human practices supersede the importance of maintaining pure water. Students will be asked to relate this discussion to events they have heard in the news — past and present — and participate in creating a class web centering on the question, "How does our water become dirty?" (Responses should include household waste, industrial waste, etc.) The web can be compiled in the same manner as described in Activity 1 or conducted as a whole group activity.

Students return to their cooperative groups and the following roles should be assigned: gatherer(s), recorder, and reporter. Each gatherer gets a margarine tub containing water and a layer of salad oil. The teacher explains that the oil represents a pollutant and asks the groups to generate ideas about how to clean the oil out of the water. The recorders list these. The students are then given the opportunity to test their theories using the materials listed earlier and the recorders write down the results of each attempt (some suggested materials could include dish detergent, popcorn, spoons, salt, sugar). The

reporters share results from each group with the class. These investigations are followed by the teacher leading a discussion focusing on what worked best and expanding the discussion to include: "What other problems arose from the cleanup?" (disposal of oil, cleanup of materials), "Can all pollutants be cleaned in the same way?," "Are there some things we can't remove from water with this type of a filter?"

NOTE: Be sure to consider invisible pollutants in the discussion (pesticides, chemicals, etc.).

Each student should record their reactions to the investigations in their individual science journals. These journals should be used consistently throughout the unit, as an ongoing activity, to record students' reflections, drawings, observations, and any other relevant information deemed important by the students or teacher.

NOTE: Teachers may consider the use of dialogue journals between teacher and students or between classmates.

Part 4. Filtering Water

Students will design, build, and test a water filtration system.

Completion Time: approximately 75 minutes for three to four class periods

Materials Needed: class web created in Activity 3, instructions on cards or charts, two liter plastic bottles, knives, mesh, rubber bands, cotton, sand, charcoal, water, dirt, vinegar, cups for runoff, pH testing kits or paper, food coloring, pebbles, various soils, crushed limestone, dishwater and oil, dishwater and food coloring, dishwater and vinegar mixtures, tempera paints, paper/pencils or chart paper/markers, student journals, any other materials students suggest for investigations.

Questions/Objectives:
How can some pollutants be filtered out of water? Is all pollution visible in water? Why or why not? What types of contaminants will or will not filter out of the systems? Why or why not? Are all types of filter systems equally effective? Why or why not?

Background Information:
The filter systems that are being designed and tested remove particles suspended in the water (mixed in, but not dissolved). Dissolved materials will go through the filtration system with the water. Teachers may want to limit "contaminants" to those that will settle out so the filter will remove them (paint and sand will filter out; sugar and salt will not).

Solutions and suspensions are types of mixtures. The difference between the two is the size of the particles involved. In a suspension in water, the suspended particles are tiny clumps of matter, both visible and invisible. In solution, the mixed particles are the size of molecules, which are tiny. Particles in solution will pass through any filter system and will not settle out over time, but will remain mixed.

The following are the general directions for building a water filtration system, but students should be afforded the freedom to create their own facilities. Place directions on instruction cards or chart paper and make available to cooperative groups if they desire them. Lay out all the materials that will be needed and let each group design and build its own system. Students can "publish" their designs and conduct their own testing instead of following the teacher directed instructions. Groups can be encouraged to make their own decisions about what types of waste water will be tested. The teacher could also present scenarios or problems to the groups, before the design stage, which could impact how the group approaches the construction of its water filtration system (i.e. if there has been an abundance of rainfall and the river is muddy, how would cleanup be handled?). Approaching the activity in this manner would provide more student empowerment and ownership. Teachers can prepare as much or as little as needed, depending on the number of students.

Procedure:
The teacher begins with a review of the previous oil spill activity and the discussion of other water contaminants (add to the pollutant web if more arise). Discuss ways to clean other types of pollutants from homes and industries. Be sure to stress

the idea (from student attempts and information presented thus far) that nothing works completely. Cleanup is a matter of what works best or does not work at all.

Have students reassemble into their cooperative groups and change roles. The teacher explains that each group will be assigned the task of designing and building a water treatment facility, using an empty two liter plastic bottle and various materials (suggested ones are listed in the materials list for Activity 4 and in the directions below). Students may use what they want, but they must come to agreement as a group before they build their facility. The teacher should explain to the whole class what materials are available prior to this portion of the activity.

1. Cut the two liter plastic bottle in half.

2. Make the six layers in the top half of the bottle as follows: Begin with one layer of cotton placed near the mouth of the bottle, follow with alternating layers of sand, charcoal, sand, charcoal, sand.

3. Secure the mesh over the mouth of the bottle using a rubber band. Place the top half of the bottle containing the layers on the lower half of the bottle. The mouth of the bottle should point down towards the bottom of the bottle.

4. Prepare dirty water by adding one part dirt to five parts of water and stir. Measure the amount of dirty water to be poured through the filter system and stir again to make sure dirt has not settled. Pour immediately through the system.

5. Measure the amount of water that went through the filter system. Save a sample for later tests.

6. Refilter the runoff two more times measuring the amount of runoff water each time. Also save a small sample of each.

7. Add 50 ml of vinegar to one of the water samples. Measure the pH before and after filtering. Record.

8. Pour the vinegar filtered water mixture through the filter system. Measure the amount of runoff that went through and its pH. Compare finding to those in the previous step. Ask: did you find any differences in the pH levels? Why?

9. Refilter the water from the last step, measure the amount and the pH of the runoff. Compare findings to the previous step. Ask: did you find any differences in the pH levels? Why?

10. Add several drops of food coloring to the filtered water. Save half of the sample for comparisons. Pour the other half through the filter system. Compare the original sample with the sample that has been filtered. Ask: do you see any differences? What are they? Why? Repeat the filtering two more times, each time saving a sample.

11. Observe any changes and discuss conclusions that can be drawn from the investigations. Record all results in journals.

VARIATIONS:
- Change the order of the layers.
- Use combinations of soils, pebbles, sand or crushed limestone.
- Encourage students to brainstorm other types of materials that could be used.

Have the students continue to test their facilities by using examples of waste water: dishwater and oil, dishwater and food coloring, dishwater and vinegar, or tempera paint. The groups will determine how successful the facilities are by comparing the filtered water with the original sample using sight and smell (EMPHASIZE THAT STUDENTS ARE NOT TO USE TASTE AS A TOOL). Recorders will chart the findings in each group and the reporters will share the results with the class. A class discussion will follow focusing on what did and did not work. The teacher also needs to emphasize that some pollutants are not detectable except through chemical tests and/or checks.

Part 5. Dealing with Waste Water

The examination of how waste water and water contamination is dealt with on a local level is the goal of this activity. This can be an effective way for students to become acquainted with scientists, government officials, agencies, and treatment facilities available in the area.

Completion Time: several days (according to focus)

Materials Needed: the book *The Magic School Bus At The Waterworks*, phone books/brochures for information on various speakers and water treatment facilities available in the local area, reference/resource materials for student research, writing paper, art supplies, videotapes, audio tapes, computers, any other materials needed for group presentations.

Questions/Objectives:
Why is it important for scientists, government officials, citizens, and others to study the effects of water pollution? Compare and contrast the advantages/disadvantages we derive from technology. How do individual communities deal with waste water and water contaminants?

Procedure:
The focus of this activity is to learn how waste water and water contaminants are actually dealt with on a local level. The class should share the book *The Magic School Bus At The Waterworks* by Joanna Cole and discuss the various facts/information provided by Ms. Frizzle and her class. The teacher and/or students should do research on what facilities and speakers are available for panel discussions and/or field trips. The class should then plan to visit a water treatment facility in the community and/or invite speakers from the area knowledgeable on the topic to learn how the community deals with waste water contaminants, oil spills, or other contaminants. In preparation for the field trip and/or guest speakers, students should be encouraged to conduct research on how water treatment/purification has changed in the community over the past one hundred years (conducting interviews should be encouraged). Also remind students to keep in mind such factors as population and how this has impacted water demand. Following this portion of the activity, it would be beneficial for students to reexamine the water treatment facilities built in Activity 4. "Why did some material filter more easily?" "What changes could now be made and why?"

Allow students to reconvene in their cooperative groups to select a topic to study in-depth, as well as decide what type of role each member should play. Some suggested topics are:

- How has water treatment/purification changed in the community in the hundred years? (Include interviews with parents, grandparents, and others as resources for information.)
- How do other counties, states and/or countries handle purification?
- How can we use sea water as a drinking water source?
- How does water pollution affect plants, animals, and land?
- What kind of technology is used in water purification/treatment?
- What types of careers deal with these issues?
- How much water do we have to use?
- What are some local water issues?
- What effects do the seasons have on water treatments?
- What is "gray" water (reclaimed water) and how is it used?

The teams will report the results to the class using a medium they prefer (written report, drawings, audio tape, videotape, etc.).

Part 6. Consequences of Contamination

Students will be asked to investigate the consequences of surface water contamination and what impact this has on the interaction with other subsystems (i.e. lithosphere and biosphere).

Completion Time: approximately 60 minutes (observations charted over a one-week period)

Materials Needed: instruction cards for each group or instructions written on chart paper (if teacher feels necessary), jars, sponges, sand, gravel,

white carnations, transparent cups, food coloring, eyedroppers, water, student journals, sugar, salt, any other materials students suggest for investigations.

Questions/Objectives:

What impact does water pollution/contamination have on the land, ground water, and plants?

Procedure:

The focus of this activity is to help realize the interconnection between subsystems by allowing students to investigate how water contaminants affect the land, ground water, and plants. It also helps to demonstrate how contaminants leach into the soil and ground water, and may be absorbed by plants.

Assemble students in their cooperative groups and once again trade roles (add reader as a new role). Each group is given an activity card describing the activity. An alternative method is to have this information written on large chart paper posted at the front of the room or at each group's work area. The reader presents the information to the group and keeps the group on task while the teacher serves as facilitator. Each gatherer gets a sponge, jar of sand and gravel, five white carnations, five transparent cups with water, and one box of food coloring.

During the first investigation, the group puts a dry sponge on top of the sand. Next, students use an eyedropper to drip four or five drops of food coloring on the sponge. Have the group predict what will happen if water is added to the sponge, record predictions in individual journals. Pour one to two cups of water onto the sponge and record the results comparing them to predictions.

Take five cups of water and add six drops of food coloring to each of four cups...the fifth cup should remain as is. Place a white carnation in each cup of water. Students should predict what will happen to the carnations, recording this information in their journals. To vary this portion of the activity, students could alter the quality of the water by mixing in sugar, salt, etc., but continue to let the food coloring represent pollutants. Ask them to note any differences that might arise as a result of this variance. Students will record their daily observations in their journals and share results after a week. The teacher should guide the discussion by asking questions such as: "In what ways were the carnations affected and how?" "Which flowers lasted longer and why?" "How can these investigations be compared to what we have learned?" "In what ways can this information be used to help us understand real life problems?" Water pollution has an effect on other subsystems: disturbance of the ecosystem, contamination of the food chain which could result in unhealthy food, animals, people and such.

PART 7. WATER FUTURES

As a culminating activity students will be given the opportunity to predict what the future holds in regard to water purification, reflecting upon past and present information gleaned from this set of activities.

Completion Time: several days (according to focus)

Materials Needed: art supplies, writing paper, computers, videotapes, audio tapes, any other materials needed for group presentations.

Questions/Objectives:

How will water purification/treatment be handled in the future?

Procedure:

Students can work individually or in groups on this culminating activity. Encourage them to utilize information they have gathered as a result of their studies during the presentation of this unit. Ask them to choose one of the two following activities to explore and prepare a presentation that will be given to the class. These presentations could include authoring a book (informational or fiction), creating diagrams/drawings, compiling interviews on videotapes/audio tapes, designing and creating models, conducting an environmental campaign, etc.

Pick a time, at least one hundred years in the future, and

- Describe how water purification will be handled considering industrial, technological, and cultural changes.
- Demonstrate the advantages and disadvantages of technology as it relates to the hydrosphere.

Extensions:

(A) Have students search for news articles relating to the topic of water purification. Have them bring these to class to post on a news bulletin board. Students take turns being a daily reporter to share pertinent information with class, or students could tape TV or radio reports giving accounts of stories.

(B) Students work in cooperative groups and create a water pollution disaster. It would be the task of the group to use creative dramatics/role playing to meet this challenge. Role assignments should include career professionals (political and scientific) as well as community members who would play a part in the simulation.

(C) Students conduct interviews with people who could offer various cultural perspectives on the importance of water and the human impact on this resource such as community members who are Native American, African American, Japanese, etc. Students could also talk with people who have lived through droughts, lived in areas where water pollution has impacted the environment, farmed areas where irrigation is required, etc. Interviews could also be conducted with professionals who work in areas dealing with water quality. Suggested interviews of professionals could include departments of natural resources watercraft division personnel, water district management personnel, hydrogeologists, water treatment facility engineers, environmental engineers, sewage treatment technicians, government officials, local water conservation and planning commission members, etc. Students could also conduct on–the–street interviews with members of the general public to ask their opinions concerning water issues. This would be an opportunity for students to check the public's awareness and understanding of environmental concerns. All of these interviews could be videotaped, audio taped, or published in book form supported by illustrations/photographs.

(D) Students conduct a more in–depth review of literature (including picturebooks, poetry, folklore, etc.) that deals with water issues. Reviews could be presented in various media and shared with older/younger classes as well as fellow classmates, a way to help educate the school community about the importance of water and the need to conserve and protect it.

(E) Students can attend meetings of government/community agencies that are considering issues dealing with water/water purification, offering input/suggestions based upon class studies of these issues.

Assessment:

This unit provides ample opportunity for cooperative learning and student choices. Alternative methods of assessment is the most effective way to evaluate student progress because "process" should be valued as much as "product," if not more. Suggested forms of assessment should include teacher developed anecdotal records/checklists/matrices, individual science journals, research projects, and the culminating activity presentations. Anecdotal records/checklists/matrices should be developed to observe individual student interactions within cooperative group activities (such as initiating ideas, offering suggestions, defending positions, encouraging others, etc.), understanding specific concepts presented in the unit study, displaying process skills, response to literature, overall engagement and participation in the classroom. Science journals can be used in various ways allowing for flexibility and individualization. Dialogue journals could be used as an ongoing assessment, as teachers would be consistently interacting and responding to student entries.

Assessment of the research projects and the culminating activity presentations will vary with the choices offered students. These provide an excellent opportunity to evaluate student progress not only in science, but across curricular areas as well (i.e. language arts areas: reading, writing, speaking, listening; math/art: models, diagrams, illustrations, drawings, etc.). Checklists or student written narratives could also be used for peer or group evaluation.

NOTE: Any of the activities here could be included in student portfolios.

Sources / Credits:

Leaching Activity — Florida's 4–Rs Curriculum.

Margaret Sadeghpour–Kramer, Iowa PLESE Participant

Chris Tonsmeire, Florida PLESE Participant

Roxson Welch, Louisiana PLESE Participant

Water Filtration System — AIMS, *Bottle Biology;* NSTA, *Water, Stones and Fossil Bones.*

Ellen Corrigan, Maine PLESE Participant

References:

Aardema, Verna, illustrated by Beatriz Vidal. 1981. *Bringing the Rain to Kapiti Plain.* Dial Books for Young Readers, NY.

AIMS Educational Foundation, PO Box 8120, Fresno, CA 93747.

Ancona, George. 1990. *Riverkeeper.* MacMillan Publishing Co., NY.

Aschenbrenner, Gerald, adaptation by Joanne Fink. 1988. *Jack, the Seal and the Sea.* Silver Burdett, NJ.

Atwood, Ann. 1971. *Haiku: The Mood of Earth.* Charles Scribner's Sons, NY.

Bellamy, David, illustrated by Jill Dow. 1988. *The River.* Clarkson N. Potter Publishers, Inc./Crown Publishers, NY.

Caduto, Michael J. and Joseph Bruchac, illustrated by John Kahionhes Fadden and Carol Wood. 1989. *Keepers of the Earth Native American Stories and Environmental Activities for Children.* Fulcrum, Inc., Golden, CO.

Cole, Joanna, illustrated by Bruce Degen. 1986. *The Magic School Bus at the Waterworks.* Scholastic, Inc., NY.

Gillespie, John T. and Corinne J. Naden. 1990. *Best Books for Children – Preschool Through Grade 6.* R. R. Bowker, NY. (Note: This is a great resource for finding books listed by subject matter.)

Glimmerveen, Ulco. 1989. *A Tale of Antarctica.* Scholastic, Inc., NY (proabaly most appropriate for students aged 9/10).

Lima, Carolyn W. and John A. Lima. 1993. *A To Zoo — A Subject Access to Children's Picture Books, 4th Edition.* Bowker, NY. (Another great resource for finding literature selections. This is more a primary level, but there are a number of picture books listed in this source that would be appropriate for sharing with upper elementary, middle, and high school students, according to the presentation and focus of the lesson.)

Project WILD. *Project WILD Aquatic Education Activity Guide.* Boulder, CO 80302.

Roberts, Elizabeth and Elia Amidon (eds.). 1991. *Earth Prayers From Around the World: 365 Prayers, Poems, and Invocations for Honoring the Earth.* Harper, San Francisco, CA.

Smith, Roland. 1990. *Sea Otter Rescue: The Aftermath of an Oil Spill.* Cobblehill Books, Dutton, NY.

Local Resource Suggestions, contact: city/county water departments; county soil and water conservation services; and state departments of natural resources.

Activity Four: Insects

Subsystem: Life

Understandings:

Earth is unique, a planet of rare beauty and great value.

Human activities, collective and individual, conscious and inadvertent, seriously affect Earth systems.

The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

Estimated Time to Complete Activity:
Four to six class sessions.

Materials Needed:
- Teacher made or commercial journals;
- small containers such as baby food jars or butter containers;
- pictures of various insects;
- art materials for painting, drawing, and creating insects (potatoes can be used to create insect bodies, small sticks or toothpicks for appendages, etc.);
- insect stories.

Part 1. What are insects?

Through literature and classifying students identify the attributes of insects.

The teacher reads a story about insects, or with an insect theme, such as *The Grouchy Ladybug* by Eric Carle, or *The Windago*, retold by Douglas Wood, "How the Butterflies Came to Be" from *Keepers of the Animals*, by Michael J. Caduto and Joseph Bruchac. After reading the story the teacher brainstorms with the students using a KWL type method. What do we Know about insects, what do we Want to know about insects, after the unit what did we Learn about insects. Students copy into their journals.

After brainstorming, the teacher presents a variety of animal and insect pictures. The students classify these pictures into groups, such as Insects and Not Insects, or further divisions based on grade level. After classifying, list the attributes that the insects have in common. You may wish to compare to human attributes. Adult insects have three main body parts; head, thorax, and abdomen. The head contains the eyes, mouth, and antennae. The thorax has six legs and sometimes wings. The abdomen contains the insect's stomach and reproductive parts. Students copy attributes into journals. See *Ranger Rick's NatureScope — Insects* for background information on insects.

Part 2A: Field Insects

Students observe, sketch, and label the insects in the school yard or nearby park.

Questions:
1. What are insects?
2. What do insects need to survive?

After a brief review of insect attributes, the teacher takes the students with their journals and pencils into the school yard or nearby field or park. As individuals or groups, students observe and list insects they find in their journals. Students will need an identification page or book to help identify the insects they have found. Check with local resources. A nearby college or university often has a "bug expert" that may be able to supply you with information.

After deciding which insect they choose to observe more closely, the students individually draw a detailed and labeled picture of their insect in their journals. Students should also describe the insect's habitat and anything else that is important to them. The teacher can decide what data are to be collected. Another important aspect to observe and study is the adaptation of the insect to live in its environment. An insect that begins its life in a creek, such as a mosquito or dragon fly, must have the ability to cling to rocks to be kept from being swept downstream. The Leaf-cutting Ant in Brazil has a special adaptation to cut leaves into small portions to carry back to the nest. What special adaptations can be found on the insects?

Upon returning to the classroom, the class as a whole group can generate a bar graph or picture graph from the data they gathered on the various insects found in the field. The students will record the class graph in their journals. Discuss ways insects have developed adaptations suitable to their environment, such as water insects having grippers on their appendages/legs to help them stick to rocks so they won't float downstream. Also discuss camouflage. See *Ranger Rick's Naturescope — Insects.* This activity may be repeated in fall, winter, spring, and summer to observe variations in insect population and activity.

PART 2B. INSECT ART

Students use collected insects to draw and paint insects.

Questions:
1. What is an insect?
2. What does an insect need to survive?

Again, in the school yard or park, students observe insects, preferably a different type of insect. Carefully collect the insects, and bring them back to the classroom. In the classroom students draw an enlarged picture of their insect, paying attention to details. After the drawing is completed the students use crayons, watercolor, colored pencils, or combinations to finish their picture. Insects should be returned to the same spot where they were collected.

As students observe and/or collect their insects they should write in their journals what their particular insect needs to survive. These should include the type of shelter or home, a source of water, and what type of food. As a class, compare the different types or amounts of each of the three supplies of food, water, and shelter. Students may need to use books or other reference materials to learn what type of food the insects eat, and from where they get their water. It is important to note that each type of insect needs all three but in varying amounts and types. These similarities and differences should be recorded into the journals. An extension could be done comparing the needs of humans and insects.

PART 3. INSECT CONTROL AND TECHNOLOGY

Questions:
1. Why do people try to get rid of insects?
2. How do people benefit from insects?
3. Why are some insects more appreciated than others?
4. How is technology used in your area to control insects?
5. What people and groups can be contacted to find out more information about insects and insect control?

After reading *Why Mosquitoes Buzz in People's Ears*, the students create a Venn diagram classifying "popular" and "unpopular" insects. "Popular" insects might be butterflies, for example, while "unpopular" insects might be flies or mosquitoes. Insects that fall "in between" might be ones such as bees that are both; they sting but they also make honey and pollinate flowers. The students should record this diagram into their journals.

As a class contact local people and groups involved in insects and insect control. Try to arrange for class speakers or information to learn how technology can be and is used locally. Encourage students to bring in newspaper articles and ads related to insects and insect control. What are positive and negative effects of insect control? How do these in turn affect humans? Students can role play and debate the different points of view in your local area. The human resources will vary from region to region.

PART 4. CREATE AN INSECT

Using their knowledge of insects, students create and build an imaginary insect and habitat using a variety of materials. Students then write a story combining factual insect information with creativity about their insect and its habitat. Students keep a field journal throughout the unit to record data, science writing experiences, factual and creative to provide accountability and assessment.

Questions:
1. What is an insect?
2. What does an insect need to survive?

As a culminating activity and as a possible assessment, students will use what they have learned and experienced to "create" an insect. This activity will combine facts with creativity to write a short story. Briefly review the attributes of insects and their adaptations to their environment. Guide students in creating insects by using a rubric (examples are given for each question):

- What does your insect eat? (peanut butter, ants, dust bunnies, etc.)
- Where does your insect live? (inside my desk, on a tree, under the couch, etc.)

- What special adaptations does your insect have that allows it to live where it does? (sticky "feet" to climb metal desks, a leg that has a spoon-like end to scoop up peanut butter, etc.)
- What are its predators? (my baby sister, my turtle, etc.)
- How does it defend itself? (bites, stings, stinks, drools, etc.)
- How does it move around? (crawls, flies, hops)

As students go through this process they begin to develop an idea of what their insect will look like. An insect's adaptations allow it to live in a certain habitat, and the insect that has been created must show this. If it hops, it must have hopping appendages; if it crawls up metal, it must have appendages that allow it to stick to metal. Provide a variety of materials for students to build their insects.

- Body parts can be made out of styrofoam balls, potatoes or other fruits and vegetables. If you use food materials to make your insects, it may be interesting to note what type of insects are attracted to the created "insects" after a period of time.
- Legs, appendages, antennae, etc. can be made out of toothpicks, sticks, pipe cleaners, straws.
- Wings, if needed, can be made with construction paper or material such as nylon stretched over wire or clothes hangers.

After students have completed creating their insect, they should review their rubric and modify their rubric or insect as needed.

Students then write a short story with their insect as the main character. The story should contain factual information from their rubric as well as a description of the insect and what it looks like, including color and size. The story should have a beginning, middle, and end, as well as a plot. Students will need help combining factual information into a story format. Possible titles include "The Bug That Ate Peanut Butter," or "The Life of the Desk Crawler." The short stories should give the reader an idea of what an insect is without being written in a report form. Students should write a rough draft to be edited by peers, parents, and/or the teacher. The final draft can be copied into journals or used to make books.

Extensions:

(A) Older students can compare the insects and habitats of the local area with the insects and habitats of other areas, such as the rain forest.

(B) A predator/prey game or food chain or web can be used to show the further interaction of spheres.

(C) This unit could be used before or after habitat studies. See the habitat activity in this book.

(D) Math can be integrated when collecting animals — the number of legs of this type of insect vs. another type, using addition, multiplication, and greater than and less than.

Evaluation:

Assessment can be done in a variety of ways or in combinations:

- Journals.
- The "created" insect and rubric from Section 4.
- The stories written in Section 3 could also be used for students to demonstrate their knowledge of insects.

Sources / Credits:

Modified and written by: Teresa Shockley – California PLESE Participant; Donna Cole – Washington PLESE Participant

References:

Ranger Rick's NatureScope — Insects. National Wildlife Federation, Washington, DC.

Caduto, Michael J. and Joseph Bruchac. 1991, 1989. *Keepers of the Animals, Native American Stories and Wildlife Activities for Children, and Keepers of the Earth, Native American Stories and Environmental Activities for Children.* Fulcrum Publishing, Golden, CO. (Teacher Guides also available)

Lima, Carolyn W. 1993. *A to Zoo - Subject Access to Children's Books*, 4th Edition. R.R. Bowker Company, New York and London.

Computer Software "Learn About Insects" (Apple IIE). Sunburst Communications, Pleasantville, NY 10570.

Earth Systems Education: Middle School Activities

Middle school offers excellent opportunities for integrating the sciences through Earth Systems Education.

Activity 1: Are You Sphere Aware?

Introduction:

In this activity students are introduced to the concept of change and how it affects the whole Earth system. They focus on how interactions within the Earth system occur. Students are introduced to the idea that the Earth consists of the interacting subsystems (spheres) known as the ***biosphere*** (living things), the ***lithosphere*** (the solid part of the Earth), the ***atmosphere*** (the gaseous part of the Earth), and the ***hydrosphere*** (the part of the Earth made up of water).

Objectives:

After completing this activity, each student will be able to:

1. Demonstrate knowledge that the Earth system is composed of interacting parts.
2. Identify change as a ever present process in the Earth system.
3. Demonstrate how change can affect various parts of the Earth system.

Science Concepts:

Cycles occur in the Earth system that cause change on or near the Earth's surface. These changes include erosion and weathering of rock and soil, earthquakes and the movement of the Earth's plates. Some of these changes are driven by energy from the Sun, others by the planet's internal heat. Changes in the Earth system also occur because of the movement of the Earth around the Sun.

At the Earth's surface, four subsystems interact including the ***lithosphere*** (the solid portion of the Earth), the ***hydrosphere*** (water), the ***atmosphere*** (air), and the ***biosphere*** (living things).

Earth System Understandings:

Earth is unique, a planet of rare beauty and great value.

The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life

Questions:

- How have artists been inspired by changes in the Earth system?
- What are the different components of each Earth system?
- How do these components interact with each other?
- How does change in the Earth systems affect each component of the Earth system?
- How have artists been inspired by interactions within the Earth system?

Introduction:

In this activity, students visually represent the various components of the biosphere, lithosphere, atmosphere, and hydrosphere in a variety of ways. They will need at least two class periods to complete this activity. The completed project should be displayed for others to see.

Part 1:

Have cooperative groups of 3–4 students each conduct this webbing activity. The students are to list everything they can think of about the Earth system and the interactions within. They should identify through this webbing activity two key concepts. The first is that there are many interactions involved in the Earth system and that these interactions have a variety of scales and times associated with them. The second concept is that change is constantly occurring in the Earth system. This change also occurs in a wide variety of scales and over varied increments of time.

Part 2:

Have students develop a collage as a group activity. Each group member should randomly be assigned one of the 4 spheres and asked to build a collage on this sphere.

Estimated Time Needed:

Two or three class periods.

Procedure:

Part 1:

1. Divide the class into groups of 3–4 students each. Each group should identify a recorder and spokesperson. A large sheet of paper and colored markers should be provided to each group.
2. Ask the class to close their eyes for thirty seconds and think about their favorite image of the planet Earth. When the thirty seconds has passed ask each student to select their image, write a paragraph about why they selected this image, and describe how this image of Earth makes them feel.
3. Once students have recorded their own personal feelings about their images of Earth, have their group develop a list of words to help them identify their personal images. Groups need to analyze the list of words generated and decide on an organization of the words (concepts) into several broad categories. Have each group provide headings or titles for their list of words and each of their categories.
3. Ask each group to share their word list and headings with the rest of the class. Discuss the different approaches taken by each group and then introduce the terms *atmosphere, hydrosphere, lithosphere*, and *biosphere*. Have each group reorganize their lists using these new headings.
4. Ask the students what is meant by the word interaction. Elicit many responses from the class and allow for discussion before reaching a good definition of an interaction. Now ask students what is meant by change. Again allow for many answers and discussion.
5. Have students identify from their list any interactions and changes in the Earth system.
6. Have student groups again share with the class the list of interactions they were able to identify and the list of changes. Assemble these lists for the entire class to see and then proceed to the next part of the activity.

Part 2:

1. In Part 2 students build a group/individual collage. This collage should show interactions and change found in the Earth system as well as the four spheres that make up the Earth system; the biosphere, lithosphere, atmosphere and hydrosphere. Each student within the group is assigned one of the four Earth spheres. He/she will construct their personal collage of the sphere. Each student group should identify the different jobs necessary to build its sphere collage, assign individual roles, decide on the format for its collage and search through available magazines to find pictures that best show the components of the various spheres.
2. As the collages are constructed, students should identify, discuss, and record on the Student Page evidence of change depicted by their collage. Students should also record any examples of interactions of components within a sphere.
3. Once the students have completed their personal "sphere" collage they are to integrate theirs with those of the rest of their team and to begin looking for evidence of interaction between each sphere. The Student Page should be used as a focus to help the group identify interactions and signs of change.
4. Students should use tape to assemble their sphere collage into one piece. Once this is completed, the group should use string to attach and show the various interactions found within the total collage.
5. Place the collages in a location for all students to view and reflect upon. Have the class discuss how each collage shows change and various interactions.

Assessment:

On an individual basis, have students develop a concept map or web showing as many changes as they can find in the total Earth system. It should answer the following questions:

1. What changes can be found in the Earth system?
2. What interactions can be found within the four subsystems of the Earth system?

References:

Adapted from an activity entitled "Are you Sphere Aware" developed by Nancy Bailey, Kraxberger Middle School, 17777 Webster Rd., Gladstone, OR 97027 as part of the 1993 Summer PLESE Workshop at the University of Northern Colorado, Greeley, CO.

STUDENT PAGE

Interactions within the Earth System

	Atmosphere	Lithosphere	Hydrosphere	Biosphere
Atmosphere				
Lithosphere				
Hydrosphere				
Biosphere				
Evidence of Change				

Activity 2: How Long is Long Ago?

Introduction:

The following series of activities is designed to help students understand the immense length of time that the Earth systems have been operating. Scientists currently believe that the Earth has existed for approximately 4.5 billion years, yet the oldest known rock is thought to be about 3.8 billion years old. These oldest rocks contain evidence of sediments that indicate that water existed on Earth prior to 3.8 billion years ago and that the water cycle and rock cycle were already in operation.

Objectives:

After successfully completing this activity, each student will be able to:

1. Describe in general terms the great expanse of geologic time.
2. Relate events that are historical, geological and biological to a time scale.

Science Concepts:

Change in the Earth systems has occurred continuously over many millions of years. This is best evidenced by the many thousands of layers of sedimentary rock which contain the remains of organisms.

Some changes in the Earth's subsystems are abrupt (such as earthquakes and volcanic eruptions) while other changes (such as evolution and atmospheric change) happen quite slowly over immense amounts of time.

Earth System Understandings:

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

Planet Earth is more than 4 billion years old, and its subsystems are continually evolving.

Questions:

- How old is the Earth?
- How long does it take for the Earth to change?

Materials:

For each student group (2 students): student sheet with 2,000 dots, calculator (teachers choice), fact sheet with historic dates, pencils for each student.

For the entire class: one unopened ream of paper, a teacher made transparency of the 2,000 dot sheet paper.

Estimated Time Needed:

One class period.

Teacher Background:

During the past 150 years, detailed studies of the Earth's stratigraphic column (rock layers) have revealed a very long and complex geologic and biologic history of the Earth. This history has been fitted together based upon the presence of fossils (biological history of the Earth) or the age of rock based upon other evidence accumulated by scientists. The history of the Earth continues to be rewritten and added to constantly as more data from locations worldwide are identified, described, mapped, and dated.

Generally scientists agree upon a system of geologic time units called ***eons***. Eons are the longest intervals into which geologic time has been divided. Eons are based upon the presence or absence of specific life forms. The following is a brief description of each eon:

Hadean Eon — The name Hadean Eon (Greek for beneath the Earth) is given to the oldest eon. This is the earliest part of the Earth's history. No rock record has yet been found of this Eon on Earth. However, rocks of this age are found on other bodies within our solar system. Rock from this Eon has been constantly recycled .

Archean Eon — The oldest known rocks found on Earth belong to the Archean Eon. These rocks contain evidence of microscopic life forms. These life forms are forms of bacteria and are the oldest known organisms (approximately 3,800,000,000 million years ago).

Proterozoic Eon — Rocks from the Proterozoic Eon include evidence of multicelled organisms lacking preservable hard parts. (Approximately 2,500,000,000 years ago.)

The Hadean, Archean, and Proterozoic Eons, also known as the "Precambrian Era," make up approximately 87% of all Earth history. Evidence of great changes in the rock cycle have been identified such as increased periods of volcanism and changes in oceanic levels. Atmospheric change during this great expanse of time is also quite evident. The earliest forms of life on Earth were anaerobic, organisms that did not utilize oxygen in their life processes. Over time these very simple organisms produced enough oxygen as a by-product of their own life processes to change the composition of the early atmosphere and led to the great explosion of life on Earth during the Phanerozoic Eon.

Phanerozoic Eon — Rocks from this Eon contain plentiful evidence of past life. The Phanerozoic Eon contains most of the fossil evidence known on Earth and is the best studied of all rock strata. This Eon began approximately 570,000,000 years ago.

The Phanerozoic Eon (Greek for visible life) is further subdivided into three *eras*. They include:

Paleozoic Era (Greek for old life) — The Paleozoic Era is known for its explosion of life and includes the first fossil record of land plants. This Era began approximately 570 million years ago and lasted until approximately 245 million years ago.

Mesozoic Era (Greek for middle life) — The Mesozoic Era is best known for the rise of the dinosaurs, which became the most dominant vertebrates on land. This Era began approximately 245 million years ago and lasted until approximately 66.4 million years ago.

Cenozoic Era (Greek for recent life) — The Cenozoic Era began as the dinosaurs became extinct. This Era has been dominated by mammals. The Cenozoic Era began approximately 66.4 million years ago and continues to this day.

Eons	Era	Period	Epoch	Million Years from now	Percent of Geologic Time
			Present	0.0	
			Holocene	0.01	
		Quaternary	Pleistocene	6.1	
			Pliocene	5.3	
			Miocene	23.7	
			Oligocene	36.6	
			Eocene	57.8	
	Cenozoic	Tertiary	Paleocene	66.4	
		Cretaceous		144	
		Jurassic		208	
	Mesozoic	Triassic		245	
		Permian		286	
		Pennsylvanian		320	
		Mississippian		360	
		Devonian		408	
		Silurian		438	
		Ordovician		505	
Phanerozoic	Paleozoic	Cambrian		570	
Proterozoic				2500	
Archean				3800 (?)	
Hadean				4650	

Procedure:

Part 1:

1. Divide the class into groups consisting of two students each and distribute copies of the fact sheet and 2,000 dot sheet to each student. This activity may also be completed individually. Do not inform students as to the quantity of dots per sheet of paper.
2. Using a teacher made transparency of the 2,000 dot sheet, demonstrate through class discussion how to proceed with this activity. Explain that each dot on the paper represents one year of time. The first dot on the upper left hand corner of the page represents the current year. Each succeeding dot sequentially represents a preceding year. Ten dots from the upper left hand corner (moving right) represents ten years ago. Work across the dot page as if you were reading a book.
3. Have students find the dot that represents the year they were born and have them circle it. Have students place a square around the year 1980. This was the year that Mt. St. Helen's exploded.
4. Have students continue circling dots that represent important years in the history of humankind. See the following list.

a.	Invention of the light bulb	1879
b.	Declaration of Independence	1776
c.	Beginning of the American Civil War	1861
d.	Pilgrims arrive in America	1620
e.	Flight of the "Kitty Hawk"	1903
f.	Columbus arrives in America	1492
g.	Norman conquest of England	1066
h.	War of 1812	1812
i.	Neil Armstrong walks on the moon	1969
j.	World War II begins	1941
k.	Atomic bomb explodes on Japan	1945
l.	Custer defeated at the Little Bighorn	1876
m.	Marco Polo visits China	1300
n.	Copernicus writes *On the Revolution of the Heavenly Spheres*	1543
o.	Invention of the telescope	1698
p.	Newton's Laws of Motion were first published	1687
q.	Darwin publishes his book *On the Origin of Species*	1859

Have students make a key so that they can distinguish between each event.

5. Help the students as they work. Be sure that each student is able to complete Part 1 before beginning Part 2. Tell students that this is an example of modeling. This is a method that scientists use to help them understand scientific concepts. The concept of time, especially long periods of time is a very difficult concept to understand and even harder to visualize. Part 2 should help students to comprehend both concepts.

Part 2:

1. Part 2 may be done as a whole class activity or small group activity. Either method will require students to explain the meaning of each answer. If completing this activity as a whole group, have students calculate one answer at a time and discuss the meaning of each. Elicit responses from students as to the meaning of each mathematical answer. Have students keep a data sheet that is to be included in their journal. This data sheet should contain their answers to each question and a "definition" for each based upon class discussion.
2. Reproduce the student activity sheet for each student. Help them as they work. Be sure that each student gets a chance to complete each question on the worksheet before they proceed to the next question. Each answer requires accurate calculations. Later questions will rely on accurate results from the earlier questions.

Questions:

1. How many dots are on the sheet of dot paper? How many years does this represent?

   (number of dots across) ______
   x *(number of dots down)* ______ = ________.

   *(50 dots across * 40 dots down = 2,000 dots.)*

   This represents __________ years.

   (1 dot = 1 year—2,000 dots = 2,000 years)

2. A ream of paper contains 500 sheets. How many years would one ream of paper represent? Check your answer with your teacher before proceeding.

500 sheets of paper x answer from question 1:
_______ = ________ years.

*(500 sheets * 2,000 years (dots) = 1,000,000 years)*

What is significant about this number?

How many sheets of paper would be required to represent this amount of geologic time?

3. How many reams of dot paper would be needed to represent 10,000,000 years?

   (Hint: divide 10,000,000 by the answer from question 2.)

   (10,000,000 years / 1,000,000 years = 10 reams)

   How many sheets of paper would be required to model this amount of geologic time?

4. How many reams of dot paper will represent 1,000,000,000 (1 billion years)?

   (1,000,000,000 / 1,000,000 years = 1,000 reams of paper)

   How many sheets of paper would be required to model this amount of geologic time?

5. How many reams of paper would be needed to represent the total length of geologic time on Earth? Earth is approximately 4.5 billion years old (4,500,000,000 years).

   (4,500,000,000 / 1,000,000 years = 4,500 reams of paper)

   How many sheets of paper would be required to model this amount of geologic time?

   *(4,500 reams of paper * 500 sheets of paper = 2,250,000 sheets of paper)*

6. Measure the thickness of an unopened ream of paper.

   (a ream of paper should be approximately 5 cm or about 2 inches in thickness)

   How high would a stack of dot paper be that represented the total age of the Earth?

   Your answer should be in feet and inches (remember, the Earth is approximately 4.5 billion years old).

   *(5 cm per ream of paper * 4,500 reams = 22,500 cm of paper)*

   (22,500 cm of paper / 100 cm = 225 meters of paper)

   *(2 inches per ream * 4,500 reams = 9,000 inches of paper)*

   (9,000 inches of paper / 12 inches = 750 feet (250 yards)

   A stack of paper 225 meters (750 feet) would be needed to represent the total length of geologic time on Earth.

PART 3:

Change over time is best evidenced by the dramatic changes in the Earth's surface and changes in the major life forms found on Earth. Using Figure 2 determine the answers to the following.

Imagine taking this stack of paper and laying it on its side. This line of paper will stretch the same length as it will be tall (see answer to question 6). This line of paper represents all of the time Earth has been known to exist. If your sheet of dot paper was found at the far right side of this line, then the left side would represent the beginning of the Earth and its various subsystems. Figure 2 represents this "stack of paper" laid on edge to represent the total length of Earth history.

Figure 2.

Beginning of Earth — You (Last Sheet)

4.5 Billion years ago — Today

|________________________225 Meters________________________|

The evidence of change in the Earth systems is found in the geologic record. This "record' records the changes in ocean levels, atmospheric changes, and the evolution of life forms. Throughout Earth history, major mass extinction's have taken place that are evidenced by the changes found in the fossil record. These major changes of life forms are the basis for dividing Earth history into eras. Using Figure 2, determine how many reams and sheets of paper will be needed to show "how long ago" various major changes in the Earth system took place.

The Precambrian Era (also known as the Hadean, Archean, and Proterozoic Eons) began approximately 4.5 billion years ago (4,500,000,000 years ago) and ended approximately 570,000,000 million years ago.

What percent of geologic time is taken up by the Precambrian Era?

At what point along your line of "paper" would you place a marker to represent the end of the Precambrian Era?

How many sheets of paper would this be?

The Paleozoic Era began approximately 570,000,000 million years ago and ended about 245,000,000 years ago.

What percent of geologic time did the Paleozoic Era occupy?

At what point along your line of "paper" would you place a marker to represent the beginning of the Paleozoic Era? Where would you place a marker that represented the end of the Paleozoic Era?

How many sheets of paper would be needed to represent this Era?

The Mesozoic Era began approximately 245 million years ago and ended approximately 66.4 million years ago.

What percent of geologic time did the Mesozoic Era occupy?

At what point along your line of "paper" would you place a marker to represent the beginning of the Mesozoic Era? Where would you place a marker that represented the end of the Mesozoic Era?

How many sheets of paper would be needed to represent this Era?

The Cenozoic Era began approximately 66.4 million years ago and is currently ongoing.

At what point in your line of papers would you find the beginning of this Era?

At what point in your line of papers would you find your own life?

Discussion Points:

1. Of these 225 meters (750 feet) of 2,000 dot paper, two sheets of paper represent most of written human history.

2. The earliest human bones and tools are about 2.5 million years old. This is represented by 2.5 reams of paper or 1,250 sheets of 2,000 dot paper. Evidence of a human presence on Earth represents only .0005% of geologic time.

   (2,500,000 years / 4,500,000,000 = .0005)

3. The Earth's history consists of 4 time intervals called eras. Each era is further divided into periods. Most of Earth's history took place in the Precambrian era. It lasted 3.9 billion years or 87% of geologic time

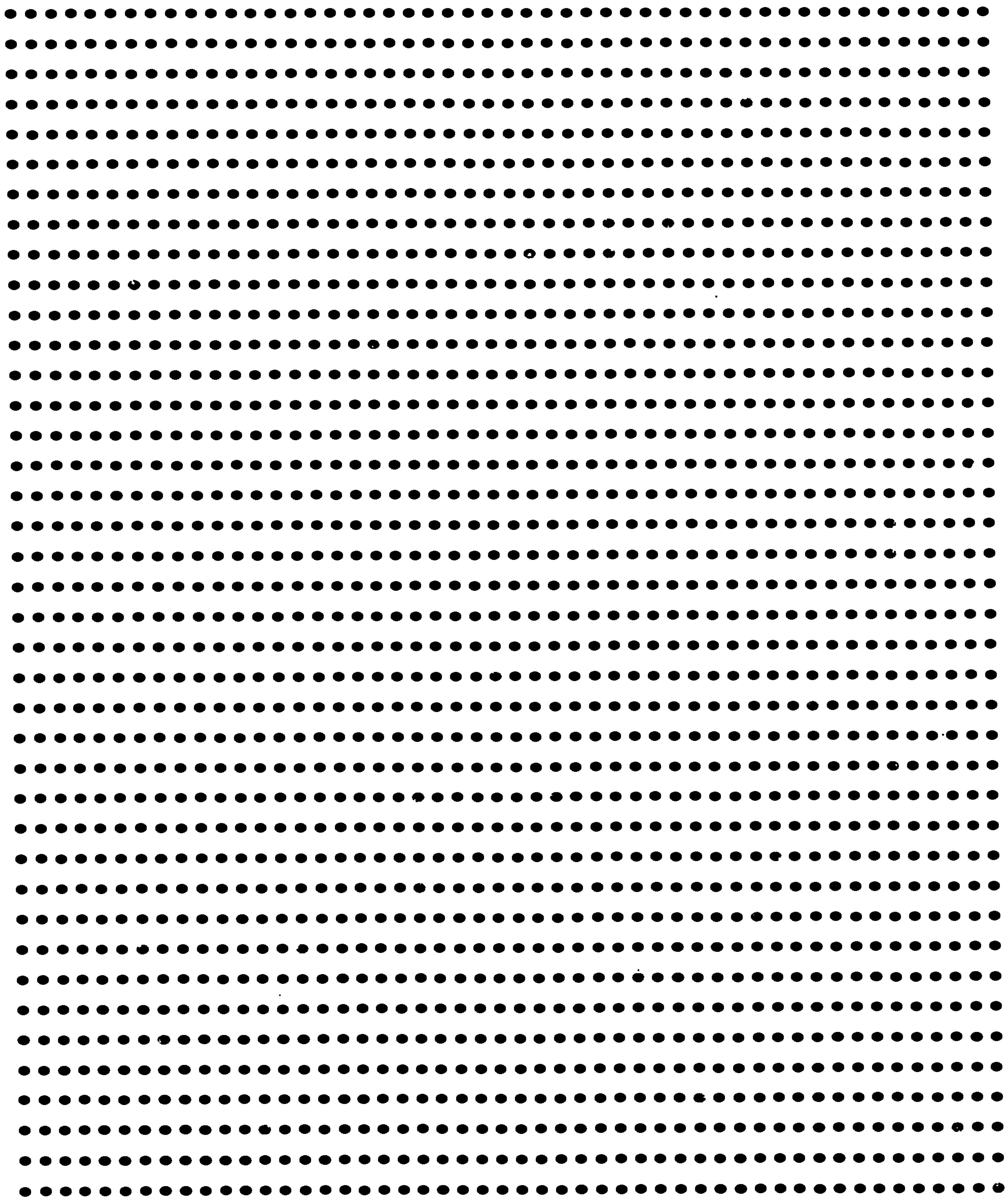
   (3.9 billion years / 4.5 billion years = 0.87 = 87 percent)

References:

Skinner, Brian J. and Stephen C. Porter. *The Dynamic Earth.*

How Long is Long Ago?

This year



Activity 3: How can the Geologic Time Scale help us understand how Earth Systems have changed?

Introduction:

The concept of change can be understood by developing a model of the geologic time scale. In this activity students locate information about Earth history and use it in a way that becomes very visual, illustrating the concept of time.

Objectives:

The student will:

1. Identify and explain changes that have occurred throughout Earth's history.
2. Identify change processes that have occurred in the past and continue to operate today.
3. Develop an understanding of geologic time.

Science Concepts:

Climates have sometimes changed abruptly in the past due to changes in one or several of the Earth systems.

Some changes in Earth systems occur very rapidly, others very slowly over millions of years.

Layers of sedimentary rock contain evidence of past changes, including fossils of past life. These fossils provide evidence for the evolution of life forms.

Earth System Understandings:

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

The Earth system is composed of the interacting subsystems of water (hydropshere), rock (lithosphere), ice (cryosphere), air (atmosphere), and life (biosphere).

Planet Earth is more than 4 billion years old, and it's subsystems are continually evolving.

Questions:

- In what ways has the Earth system changed throughout time?
- How have organisms (biosphere) interacted with the other subsystems?

Teacher Background:

Scientists have validated theories of crustal evolution and organic evolution through evidence found in the rock record. They also agree that there is a great degree of support for the idea that both have influenced climate.

Materials:

Books and materials about life during geologic time, popsicle sticks, 5 x 7 index cards, permanent markers

Procedure:

Part 1:

1. Organize students into teams of four.

2. Depending on the size of your class, assign student groups the following eras for study: The Precambrian, Paleozoic, Mesozoic, Cenozoic, and present. If necessary, larger groups of students can be made up for the Paleozoic, Mesozoic, Cenozoic, and present time periods or you can divide specific eras up into smaller sections.

3. Students will assume the following roles in their groups:

Climatologist / Hydrologist — Responsible for finding information on the change of climates and ocean levels that seem to have occurred during their particular era of study.

Botanist — Responsible for finding information on the change of plant types that seem to have occurred during their particular era of study. Students are to document all "dates" of each change and are to find specific facts about any and all plant types.

Zoologist — Responsible for obtaining information on the change of animal types that seem to have occurred during their particular era of study. Students are to document all "dates" of each change and are to find specific facts about any and all animal types.

Geologist — Responsible for obtaining information on the changes involving plate tectonics and other geologic phenomena that seem to have occurred during their particular era of study. Students are to

document all "dates" of each change and are to find specific facts about any geologic events.

Each student will become an expert on the topic and era assigned. Each will act as a resource on the topic for the entire class.

Each group of students is to produce two products from their research. First they are to make "signs" that represent significant changes that have occurred during their era. Each group will obtain information about plant and animal life, climatic/oceanic conditions, and geologic formations found during their period of time. Students will make special note of the arrival of new organisms and the extinction of organisms. Special attention should be given to all forms of change that occurred. These "signs" should include pertinent facts about the event and the approximate time of when it took place. The signs should be attached to wood stakes (popsicle sticks work well). Have students build their "signs" with sticks and 5 x 7 index cards. The signs will later be used to construct the whole class time line in Part 2.

PART 2:

1. For this part of the activity, use a scale of 5 cm = 1 million years, or 1 m = 20 million years. This scale conforms with Part 3 of "How Long is Long Ago?"—the previous activity in this unit. The total length needed for the time scale is 225 meters. The activity can be done either outside or inside. The scale can be changed to accomodate the space available.

2. On your time scale, identify the periods in your era. Identify and mark the beginning time of each period and the time the period ended in millions of years prior to the present. Place cards representing these points in history at the exact location on the class time line (refer to the activity "How Long is Long Ago?" for help in determining these locations).

3. Now place each of your "signs" along the appropriate location in the time line. Check your calculations

4. After you have plotted your data and information on your time line, organize your information in a table similar to the one below. Remember to keep the most recent information at the top of your table, with the oldest information at the bottom of the table. A separate table should be made for each period of geologic time.

5. Have students walk as a group to each era along the time line beginning with the Precambrian Era. Have the students that were responsible for this information give a presentation to the rest of class about the information they found. Have students concentrate on changes that occurred instead of "facts and dates." As the Precambrian group completes their presentation proceed up in time to the Paleozoic era and have this group make their own presentation. Allow time for each "Era Group" to make their own presentation along their part of the time line. Require all students to complete a "data sheet" for each era. It should include responses to the following questions:

- What did you learn about the plant and animal life in your era?
- Describe the physical environment of the Earth.
- Describe the climatic environment of the Earth
- In what ways did each of your eras change over time?

6. Have students discuss the following questions:

- What changes in the lithosphere have occurred throughout geologic time?
- What changes are still occurring today?
- What evidence do you have of mass extinctions?

Years Ago from Today	Period	Plant Types	Animal Types	Climate	Geologic Events

Assessment:
Use assessment forms such as rubrics, checklists, concept maps, and individual reports. Empphasize student understanding of the connections between the systems during each of the eras.

Extensions:
Have each team of students write an article for their particular time period. Display them for the class.

Sources/Credits:
Braus, Judy. 1988. *NatureScope Geology: The Active Earth.* Washington, DC: National Wildlife Federation.

References:
Skinner, B.J. and S.C. Porter. *Th^e Dyn amic Earth.*

Activity 4: How Have All the Species Gone?

Introduction:
The Earth System has experienced great change through its history. Natural cycles, such as the rock and water cycles, have been fundamental in the shaping and reshaping of the Earth's surface. At the beginning of the Cambrian Period of the Paleozoic Era, a huge explosion of life began as is recorded in the rock layers. This new biological activity became a change agent just as powerful as the rock and water cycles had been. It produced enough oxygen during the Precambrian Period to literally change the makeup of the Earth's atmosphere. Organisms began to use nitrogen, carbon dioxide and oxygen in their life processes.

The Mesozoic Era saw a great change in animal and plant life on the lithosphere. This change included the age of dinosaurs and the appearance of early mammals followed later by the first flowering plants.

This series of activities is designed to have students look at how scientists search for evidence of changes in the past and how they develop theories to expain this evidence.

Objectives:
The students will:

1. Relate the development of dinosaurs to other events in Earth's history.
2. Describe the concepts of mass extinction, background extinction, punctuated equilibrium and stasis.
3. Interpret the possible causes of mass extinction using geological evidence presented in science literature
4. Analyze the past and present rates of extinction
5. Identify human and natural environmental reasons for extinction

Science Concepts:
Some changes in the Earth system are very abrupt and can be caused by extraterrestrial events such as the impact of a meteorite or by an Earth systems such as ourselves.

Earth systems tend to change until they become stable. They will remain that way until some outside influence affects them.

Earth System Understandings:
Earth is unique, a planet of rare beauty and great value.

The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

The Earth system is composed of the interacting subsystems of water (hydrosphere), rock (lithosphere), ice (cryosphere), air (atmosphere), and life (biosphere)

Planet Earth is more than 4 billion years old, and it's subsystems are continually evolving.

Earth is a small subsystem of a solar system within the vast and ancient universe.

There are many people with careers that involve study of the origin, processes, and evolution of Earth

Questions:
- In what ways does the Earth system change?
- How accurately does the Disney movie *Fantasia* depict Earth history?
- How did the Disney artists use art and music to convey their interpretation of Earth history?

Teacher Background:
Most scientists agree that dinosaurs lived on Earth for approximately 165 million years. This period of time is known as the Mesozoic Era and is divided into three time periods, the Triassic, the Jurassic and the Cretaceous periods. The division between each of these periods of time is marked by changes in the life forms, especially those found in the Earth's oceans, with some becoming extinct and new ones moving into various niches found within the global ecosystems. A now famous mass extinction took place at the end of the Cretaceous Period which seemed to have ended the dinosaurs' reign on Earth. Most geologists agree that this was caused by a meteorite impact and that such meteorite impacts caused extictions many times throughout Earth history. Currently a mass extinction is occurring that is more severe even than the Cretaceous one. It is caused by humans as they destroy species and their habitats.

PART 1: HOW DID THE DINOSAURS LIVE?

Materials:
a TV and VCR, *Fantasia* on video

Estimated Time Needed:
A total of two class periods will be needed to complete Part 1.

Procedure:
In this part a segment of the classic movie, *Fantasia*, is used to review the development of the Earth and its life forms, and to introduce the extinction of the dinosaurs, a central topic for this activity.

In the movie, the Disney artists provide a unique interpretation of Igor Stravinsky's **"The Rite of Spring."** It begins approximately 40 minutes into the commercially available video and lasts for twenty minutes.

1. Play the segment for your students. Suggest that they listen to the music to see if they can correlate sounds and instruments with events depicted on the screen.

2. Divide the class into groups of four students each. Play this section of the tape a second time. Assign each student in each group one of the following jobs:

Geologist — These students are responsible for describing and gathering evidence of change in the way the Earth looks. They are to focus in on the lithosphere.

Biologist — These students are responsible for describing and gathering information on the many changes that take place in the biosphere. They are to include an identification of each life form and to record what appears to be major changes in life.

Hydrologist / meteorologist — These students are responsible for recording evidence of changes in sea level and changes in the atmosphere.

Artist — These students are responsible for the recording and interpretation of how the music and art are intertwined to tell a story.

3. After showing the video *Fantasia* a second time have students organize into their groups to discuss their observations. Each group should then develop a report that includes components from each of their jobs. Emphasis should be placed on how change takes place in each Earth subsystem. Have each group select a spokesperson who will represent the group's observations.

4. Arrange large sheets of paper in the front of the room to record group observations from each assigned role. Place the following headings on each sheet: Geologist Report, Biologist Report, Hydrologist/Meteorologist Report, and Artist Report. Select a student to record observations that each group makes. Conduct a class discussion starting with the representative of each group presenting the group's report to the class. The class discussion should focus on differences

in observations, interpretations, and analyses between the various group reports.

5. This movie was produced over 50 years ago. Have your students determine the degree to which current scientific thought agrees or disagrees with that depicted in the movie. They should especially address the following:

- how the Earth, the atmosphere, and the water in the oceans were thought to form
- the "life style" of the dinosaurs
- the probable cause for the extinction of the dinosaurs

[It is interesting to note that the behavior of the dinosaurs as depicted in the movie was widely criticized by the scientific community at the time. It was thought that dinosaurs were slow, lumbering solitary creatures of very low intelligence. However, recently paleontologists have found evidence that certain species had a herding instinct, that family groups stayed together for years, and that some were very active, speedy creatures; much as they are depicted in the film. This points out how science is dynamic. Its explanations change as new data is found and interpreted.]

*[It might be interesting, at the beginning of this activity to show a segment of a movie which contains humans and dinosaurs in the same scenes. A movie such as **The Land That Time Forgot** has many such scenes. Ask your students to compare the two movies and consider which one is more scientifically correct. Does the fact that one is animated make it less scientific?]*

Part 2: How and Why do organisms become extinct?

Materials:

Two sets of cards reproduced and laminated. These cards should represent animal and plant species that existed during the Mesozoic Era and those that existed during the Cenozoic Era.

A clock with a sweep second hand visible to all students in the classroom.

Number the Mesozoic card set as follows:
a) individually 1 through 7
b) all remaining cards with the same number, 8

The Cenozoic cards should be numbered sequentially, 1 through 20.

Prepare duplicate cards from each set so that every student can receive a card from each set.

Procedure:

1. Using classroom and library resources, have students identify three to five "facts" about their organisms from the Mesozoic era. Facts should include when and how the organism lived, and when it evolved and became extinct. Have them describe to the rest of the class the facts they found.

The Simulation:

2. Have one student volunteer to be the "extincter." Explain to the class that the movement of the hands of a clock will represent the passage of geologic time. One minute will equal approximately 6 million years.

3. Ask students to stand beside their desks holding their Mesozoic Cards so that other students can see what species they represent. Provide students with a "data chart" so that they can record when each species becomes extinct.

4. Have the extincter call out card numbers 1 through 5 at 30 second intervals. The student or students holding these numbered card(s) are to sit down thus representing the removal of that species from the Earth.

5. At the end of the third half minute (9 million years) ask the class to explain the process this represents (background extinction).

6. At the end of the fourth half minute (12 million years) ask the class whether there have been any other changes (other than background extinctions) among the populations of animals over the past 15 million years? Discuss the concept of stasis (little change in populations over long periods of time).

7. At the end of the fifth half minute (15 million years) have the extincter call number 8 (a mass extinction event). All but two of the remaining species will now be sitting (extinct). Discuss possible causes of such a mass extinction.

8. At the end of the sixth half minute (18 million years), have the extincter call out number 7. This continues the example of background extinction.

9. Immediately give each sitting student a new species card from the Cenozoic set of cards. Have them all stand at the same time.

[This expansion in life forms represented by the new Cenozoic cards is called adaptive radiation. This is a period when organisms adapt to new habitats and environments in a relatively short geologic period of time.]

10. Have the extincter continue background extinctions every half minute starting with the number 1. Discuss with students the concepts of stasis, mass extinction, background extinction, and adaptive radiation.

11. Summarize this activity by discussing the concept of punctuated equilibrium as a mechansism for change in species.

[The idea of punctuated equilibrium arose through studies by Eldredge and Gould as documented in Eldredge's book, Time Frames. Instead of evolution (change) proceeding at a slow constant rate they presented considerable evidence over the years that very little evolution would proceed during "normal times." There would be a slow rate of background extinction with a few new species arising from mutation (stasis). Eventually there would be dramatic change in the environment with many species becoming extinct. This would be followed by a rapid development of new species adapting to and radiating into the now vacant habitats (adaptive radiation). And once again, stasis would exist as long as there were no dramatic environmental changes.]

Assessment:

Use checklists or rubrics to evaluate the level of student understanding of the science concepts stated at the beginning of the activity.

Extensions:

Suggest to students that they produce their own videos or cartoons depicting elements of Earth history. They should chose art works as well as music to help them tell their story. The class should observe the products.

Students can develop a scrapbook or collage with in-depth information about one of the plant or animal species in the simulation.

Sources / Credits:

Boucot, A.J. 1990. *Evolutionary Paleobiology of Behavior and Coevolution*. New York: Elsevier Science Publishers.

Finsley, C. 1989. A field guide to fossils of Texas. Austin: Texas Monthly Press.

Walt Disney Home Video. *Fantasia*. Buena Vista Home Video, Dept. CS, Burbank, CA 91521.

References:

Eldredge, Niles. 1985. *Times Frames*. Simon and Schuster, Inc.

Fortner, R.W. and V.J. Mayer. 1993. *Activities for the Changing Earth System*. Columbus, OH: The Ohio State University Research Foundation.

Student walking the Cenozoic end of the geologic time line in Cincinnati's Bicentennial Park. This time line has illustrations of prominent life forms and descriptions of significant geological events.

Biological and Earth Systems Science

A Two–Year Integrated Science Course for Grades 9–10 of the Worthington, Ohio, City Schools

This information is adapted from a brochure developed by the BESS teachers to provide students and their parents with detailed information about this dramatically different science program. The first year of the course is required of all students. The full two-year program is a prerequisite for all higher level science courses in the three district high schools. A sampler of activities used in the course follows this descriptive information. They are keyed into the course outline and enclosed in (parentheses).

The Genesis of Biological and Earth Systems Science

We are being presented with almost daily reminders of the result of abuse and neglect of our Earth system such as global warming, ozone depletion and problems of hazardous waste disposal. Our continuing dependence on oil as an energy source has worldwide political repercussions. In general, the public has been ambivalent toward science and has a poor understanding of what science is telling us about the Earth. Thus there is an immediate need to restructure the science curriculum to ensure that present and future citizens will be scientifically literate, that they will understand the interrelationship between science, technology, and society and the impact that their actions have upon our home, Earth.

The viewpoints expressed in the statement above have led to some of the most massive research ever undertaken in curriculum development. Many national projects initiated during the 1980s are only now beginning to affect our curriculum. Science education has seen the highest monetary expenditure of any area of curriculum reform. Two studies which have had a direct impact upon the development our Biological and Earth Systems Science curriculum include "Project 2061" of the American Association for the Advancement of Science (AAAS), and the "Scope, Sequence, and Coordination" (SS&C) effort of the National Science Teacher's Association (NSTA). Therefore, several groups of science educators came together to revise science curriculum in a manner consistent with an Earth systems view. First, the National Science Foundation supported a group of leading educators and geoscientists in 1988 to identify the goals and concepts about the planet Earth that "every 17–year old should know." A member of the Worthington School science staff attended this conference in response to studies already underway within the Worthington Schools. These activities on the national level led to the beginning of the BESS curriculum model.

The concepts and goals which were produced as a result of the work of the above groups were combined and submitted to a national group of science educators meeting at The Ohio State University in May 1990. This group has become known as the "Program for Leadership in Earth Systems Education" or PLESE. The results of this meeting are the broad concepts we undertake in Biological and Earth Systems Science. The syllabus and teaching materials for this class revolve around a study of the Earth and the subsystems which make it a whole.

> *The goal of science education during the 1980s is to develop scientifically literate individuals who understand how science, technology, and society influence one another and who are able to use this knowledge in their everyday decision–making. The scientifically literate person has a substantial knowledge base of facts, concepts, conceptual network, and process skills that enable the individual to continue to learn and think logically. This individual both appreciates the value of science and technology in society and understands their limitations.*
>
> —from NSTA's position paper on Science, Technology, and Society

BESS Learning Strategies

Based upon current research in science education, science should be less teacher–centered with an emphasis on the student and on the process of learning science. In designing the BESS program, these considerations were taken into account. BESS places an emphasis on:

- Problem–based learning
- Use of current technology
- Information acquisition
- Analysis, evaluation, interpretation and application of information
- Group learning

A variety of strategies are employed to facilitate the learning process. These strategies include laboratory work, projects, peer teaching, field experiences, lecture, and discussion.

Assessment techniques used in BESS are designed to measure a student's understanding of material and a student's ability to analyze, evaluate, and apply information. Forms of such assessment have included student designed and constructed newspapers, videotaped programs, computer programs, simulation aids, reports and projects which emphasize science as a process rather than just a product. More traditional forms of assessment, such as tests and quizzes are also part of student evaluation.

BESS Desired Learner Outcomes

- A holistic understanding of planet Earth.
- Aesthetic appreciation of nature.
- Understanding individual organisms, each one's place in a system, and its part in environmental processes.
- Awareness of of human activities' impact on the planet Earth.
- Demonstrate wise use of Earth's limited resources.
- Use of current technologies as tools to access and process information.
- Define problems and issues, and use skills for analyzing issues and solving problems.
- Demonstrate individual and collaborative scientific endeavors.
- Demonstrate effective communication skills within the context of science.
- Understand the basic concepts and principles of science and apply them to solve problems, make decisions and understand the world.
- Demonstrate awareness of science related skills and careers.

Ed Shay, one of the orginators of the BESS program instructing his students at the Linworth Alternative School in Worthington, OH.

BESS 1 Framework (Ninth Grade)

A. EARTH'S NATURAL SYSTEMS

A1 What is a system?
A2 Why is diversity important in a system?

(Activities—Symposium to Save a Species; Endangered Species Pamphlet; and Environmental [illegible] an Organism)

A3 How and why do scientists classify parts of systems?
A4 How do Earth's natural systems change?
A5 What are some issues or concerns regarding Earth's natural systems?
A6 What tools and processes are used to study natural systems?

B. REMOTELY SENSED INFORMATION

B1 How are maps, aerial photos and satellite images used?

(Activity—Re-Introduction of *Castor canadensis* to Harveysburg)

B2 How do comparisons of data/information over time show change?
B3 How do ground observations provide clues for the interpretation of aerial photos and satellite images?
B4 How is remote sensing used in astronomy and medical sciences?
B5 What are some issues or concerns regarding change and remote sensing?

C. WEATHER SYSTEMS

C1 How is remote sensing used to study weather systems?
C2 What is the source of energy in our atmosphere?
C3 What causes weather to change?
C4 What are the interactions between large bodies of water, land, and atmosphere that influence weather?
C5 How can changes in the weather be monitored and predicted?
C6 How does weather affect you, and how does it affect other organisms?

(Activity—Weather in our Lives; How Effective is a Carbonate Rock at Storing Carbon Dioxide?)

C7 What causes violent weather such as blizzards, tornadoes, thunderstorms and hurricanes, and how can you protect yourself from these?
C8 What are some issues or concerns regarding weather systems?

D. EARTH'S NATURAL RESOURCES

D1 What are Earth's major natural resources and how do we use them?
D2 What are our responsibilities toward the use of natural resources?
D3 Which natural resources are renewable or nonrenewable and how can or should they be managed for sustainability?
D4 What are some of the positive and negative impacts of acquiring and utilizing natural resources?

(Activity—The Gaian Game; Microrganisms in the School Environment)

D5 What are some organizations involved with environmental stewardship?
D6 What are some issues or concerns regarding Earth's wastes, pollutants, and natural resources?

E. ECOSYSTEMS

E1 What remote sensing techniques are used to study ecosystems?
E2 How do landforms and soils develop?
E3 How does energy flow within an ecosystem?
E4 What are some interrelationship in an ecosystem?
E5 What are some issues or concerns regarding ecosystems?
E6 How are ecosystem relationships altered and what are some of the results of these changes?
E7 What are the factors that make terrestrial and aquatic biomes in the world unique?

(Activity—Biome Booth; Soil Analysis)

E8 What effects do biomes have on global environments?

F. CULMINATING ACTIVITY

Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the first year of BESS.

(Culminating Activity)

BESS students at Thomas Worthington High School working on their team project.

BESS 1: CONCEPTS AND CONTENT

Unit A: EARTH'S NATURAL SYSTEMS

Examples of Systems
Earth's Subsystems
Biodiversity
Biological Classification
Biotic/Abiotic Factors
Dichotomous Key
Examples of Change in Systems
Population Dynamics
Solar System
Remote Sensing Devices
Cause and Effect Interrelationships
Interrelationships

Unit B: REMOTELY SENSED INFORMATION

Map Scale
Latitude/Longitude
Topography
Remote Sensing Devices
Uses of Remote Sensing (Medical, Astronomical, Environmental)
Indicators of Change

Unit C: WEATHER SYSTEMS

Seasons
Emergency Readiness
El Nino
Convection Cells
Warm and Cold Fronts
Climates
Jet Streams
Storms
Land/Water Interactions
Water Cycle
Collecting Weather Data
Forecasting

Unit D: EARTH'S NATURAL RESOURCES

Formation of Resources
Habitat Destruction
Renewable vs. NonRenewable
Alternative Resources
Stewardship Organizations
Reduce/Reuse/Recycle
Human Influenced Global Climate Change

Unit E: ECOSYSTEMS

Introduction to Natural Selection
Glaciation
Food Chains/Webs
Energy/Biomass Pyramids
Biogeochemical Cycles
Trophic Levels
Biomes/Ecosystems
Niche
Community Relationships
Soil Development
Adaptions (Structural, Morphological, Uses of Chemicals, Behavioral)

BESS 1: Problems and Issues

Unit A: EARTH'S NATURAL SYSTEMS

Whaling
Marine Mammals
Deforestation
Endangered Species
Extinction
Zero Population Growth
Hunting/Fishing/Poaching
Human Population Growth
Environmental Ethics
- Zoos/Preserves
- Stewardship

Unit B: REMOTELY SENSED INFORMATION

Land Use/Urbanization
Documentation of Change
Uses of Satellite Data (i.e., deforestation, ozone depletion, storms and weather, population growth)
Familiar Places

Unit C: WEATHER SYSTEMS

Weather Technology
Global Climate Change
Emergency Readiness
Artificial Weather Control
Droughts (i.e., cloud seeding)
Planning for Weather Changes

Unit D: EARTH'S NATURAL RESOURCES

Air Quality/Pollution
Natural Resource Depletion
Land Allocation
Ground Water Contamination
Fossil Fuel Depletion
Synthetic Replacements
Jobs vs. Environment
Reduce/Reuse/Recycle

Unit E: ECOSYSTEMS

Pesticides
Wildlife Preserves
Wetlands Destruction
Oil Spills
Rainforest Destruction
Deforestation
Soil Quality
Desertification
Antarctica
Food Additives/Alterations
Acid Rain
Man-made Chemicals
Asbestos
Naturally Occurring Chemicals

BESS 2 FRAMEWORK (TENTH GRADE)

G. REVISITING SYSTEMS

(Activities—Microcosm Lab and Analysis; Create an Ecosystem)

H. ORGANISMS AS SYSTEMS

H1 What technologies are used to study individuals?
H2 What is the internal structural organization of organisms?

(Activity—Cell Organelle Trade Show)

H3 How do the internal subsystems of an organism function and respond to changes?
H4 What are the main biochemical processes that sustain organisms?
H5 How do the structures and biochemical processes of organisms function interconnectedly to achieve essential matter and energy exchanges?
H6 What are some factors that may change the normal functions of an organism's subsystems?
H7 What are some issues or concerns regarding the well-being of individual organisms?

I. THE EARTH AS A SERIES OF INTERACTING SYSTEMS

I1 How can changes in Earth's subsystems be monitored and predicted?
I2 What are the causes and effects of crustal evolution and other major changes in Earth's subsystems?

(Activities—We're Gettin' All SHOOK Up!; Change; Plate Tectonics)

I3 How does matter move through biogeochemical cycles involving different subsystems?
I4 What can fossils and other Earth archives tell us about the nature of and the rate of changes and interaction in Earth's subsystems?
I5 How and why are humans altering Earth's subsystems?
I6 What are some issues or concerns raised from these alterations?
I7 What should we do to minimize our negative impacts on changes in Earth's subsystems?

J. ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

J1 How do the major natural processes that may result in changes in species work?
J2 What changes in genetic diversity may result from these processes?
J3 What evidence is there for organic evolution?

(Activities—Jurassic Park Activity; Mutations and Misconceptions; SimLife Project

J4 How are genetic information molecules replicated, transmitted, expressed, and altered?
J5 What are the mechanisms and principles of genetics/heredity?
J6 How and why are humans altering natural genetic and/or reproductive processes?
J7 What are some potential implications and impacts of these alterations?
J8 What are some issues or concerns raised by these alterations?

K. CULMINATING ACTIVITY

K1 Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the second year of BESS.

BESS 2: Concepts and Content

Unit G: REVISITING SYSTEMS

Chaos Theory
Earth's Subsystems Review

Unit H: ORGANISMS AS SYSTEMS

Atomic Structure
Cell Struction and Function
Plant Organ Systems
Animal Organ Systems
Energy Requirements of Organisms (e.g. enzymes, cellular respiration and photosynthesis)

Unit I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

Minerals
Rock Cycle
Weathering and Erosion
Oceans
Rock Strata
Fossils
Plate Tectonics
Earthquakes and Volcanoes
Continental Drift

Unit J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

Genetics/Heredity
Mitosis
Meiosis
DNA Replication
Protein Synthesis
Geologic Time Scale
Evidence for Evolution (e.g. fossil record, biochemical and geographic)
Mechanisms of Evolution (e.g. mutation, recombination, and natural selection)
Nonhuman Influenced Global Climate Change

BESS 2: Problems and Issues

Unit G: REVISITING SYSTEMS

The State of the World Today
Chaos Theory
What's New in the World/Instabilities

Unit H: ORGANISMS AS SYSTEMS

Toxic Substances
Chemical Deficiencies
Carcinogens
Parasites
Bacterial/Fungal/Viral Agents
pH/Temperature Variations
Animal Research/Welfare
Euthanasia
Organ Transplantation

Unit I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

Waste Disposal
Mining
Ocean Dumping
Shore Erosion
Sea Level Changes
Shore Modifications
Stream Channelization

Unit J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

Mutagenic Agents (suntanning)
Gene Therapy
Genetic Counseling
Artificial Selection
Reproduction Technologies
Moral/Ethical Implications
Genetic Engineering and Biotechnology
Cloning
Fertility Enhancement
Artificial Insemination
In Vitro
Surrogacy

BESS Types of Activities Used

Unit A: EARTH'S NATURAL SYSTEMS

- Pond and river studies
- Classification methods
- The Solar System
- The scientific method
- Microscope and classifications labs
- Student developed computer programs
- Nature walks
- Access on-line database
- Systems science
- Population studies

Unit B: REMOTELY SENSED INFORMATION

- Reading topographic maps
- Use of technology in the medical field
- Types of equipment used to gather information about the universe
- Use aerial photography to investigate our local environment
- Investigate what we can learn and use from satellite photos
- Use CD-ROM technology to investigate remote sensing techniques
- Satellite images of Earth
- Map skills
- Changes in Worthington

Unit C: WEATHER SYSTEMS

- Investigating the weather page of the newspaper
- Computer simulation games to investigate pollution associated with cities
- Student-made newspaper or weather television show
- Investigate the depletion of the ozone layer and prevention of this
- Investigate global warming—causes and effects
- Labs on the amount of carbon dioxide stored in certain types of rocks
- Air temperature and pressure labs
- Causes of wind and weather patterns

Unit D: EARTH'S NATURAL RESOURCES

- Energy resources
- Agricultural resources
- Building resources
- Recreational resources
- Food resources
- Ore extraction lab
- Ohio's coal industry
- Methods used to obtain natural resources and associated problems

Unit E: ECOSYSTEMS

- Become an expert regarding a specific biome, and create a biome booth
- Investigate ways that we have altered or could alter our biome
- Food webs and energy pyramids
- The legacy of glaciers in Ohio
- Ecological relationships
- Soil studies
- Trouble with water
- Adaptation activities
- Groundwater
- Soil types
- Water issues
- Trophism labs
- Microbiology labs
- Permeability and porosity lab

Unit F: CULMINATING ACTIVITY

Students will be involved in culminating activity which will explore and integrate many of the concepts and ideas developed during the first year of BESS.

Unit G: REVISITING SYSTEMS

- Microcosm experiment
- Construction and study of ecocolumns
- The science of composting
- Sphere interaction studies
- Aesthetic field trip
- Everything is connected to everything
- Field studies plots

Unit H: ORGANISMS AS SYSTEMS

- Cell structure and function
- Cell doctor
- Organelle trade show
- Protease lab
- Catalase lab
- Cell energetics Hypercard Stack
- Organ systems project
- Cell processes games

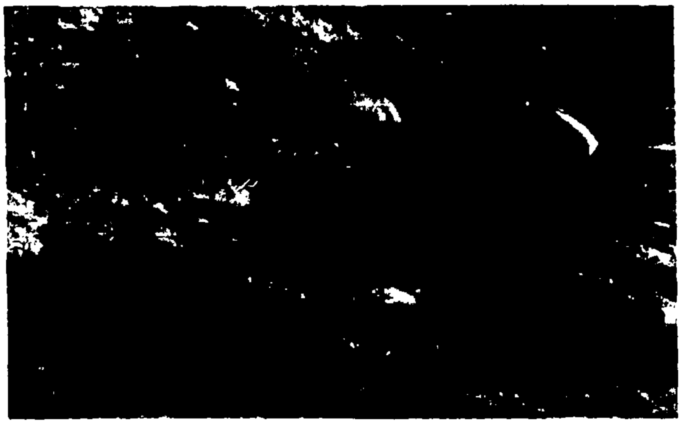
- Biomechanics and biceps
- Cell model building

Unit I: THE EARTH AS A SERIES OF INTERACTING SYSTEMS

- Geologic time
- Rock cycle
- Fossil marking and identification
- Radiometric dating simulation
- Sedimentary processes: stream table
- Igneous processes
- Volcanoes and climate
- Ice core activity
- El Nino activity
- Town Hall meeting dealing with changes
- Downeaster Alexa
- Crustal ocean evolution
- Ecological succession
- Climate system changes
- "Great Quake of '89" interactive laser video disc

Unit J: ORGANIC EVOLUTION, GENETICS AND BIOTECHNOLOGY

- Dropping your genes: a genetics stimulation in meiosis, fertilization, and reproduction
- Gender change research
- A study of DNA: The molecular basis of heredity
- Marshmallow meiosis: the reebop activity
- Family genealogy and heart disease



Vic Mayer, PLESE Project Director, hunting for trilobites in the Ordovician of southern Ohio. Photo by Suck-wan Choi.

- Change through natural selection
- *T. rex* exposed
- *Jurassic Park*
- Wings genetics program

Unit K: CULMINATING ACTIVITY

Students will be involved in a culminating activity which will explore and integrate many of the concepts and ideas developed during the second year of BESS.

Support Materials for BESS

Macintosh computers
Biology textbooks
Earth science textbooks
Environmental science textbooks
Microsoft Works
Hypercard
Superpaint
Computer simulations
Videotapes
Videodiscs
CD-ROM
DeltaGraph
Ohio State University
School library
IBM compatible computer
Camcorder
Spinnaker Plus
Computer graphics
Computer sound edition capabilities
Periodicals
Atlases, almanacs, and dictionaries
BESS library
Optical scanner
35–mm camera
CompuServe
Biology and Earth science laboratory materials
Satellite images and aerial photographs

A–1

Symposium to Save a Species

Introduction

The newly founded International Endangered Species Organization (IESO) has recently announced they will be holding an open meeting for the purpose of presenting $5,000,000 to an organization for a plan to save endangered species. The IESO will be concerned with how the moneys will be used to save that species. Things to consider are: identification of causes of endangerment, plans to alleviate the causes, and generation of public awareness.

Any group which is concerned with working to save an endangered species is encouraged to present a proposal to IESO for the five million dollar grant.

Group Objectives

The objective of your group will be to represent an environmental organization concerned with the preservation of a particular species. It is the group's decision as to which species you want to save. The only requirement is it **must** be an endangered species.

Once your group has decided upon the species to save, you need to determine a strategy for saving that species. This strategy needs to include:

1. What information is needed about the species and its endangerment.
2. Methods to stop the reasons for endangerment.
3. How the money will be spent (considering both the species and the public).
4. Type of information that needs to be presented to IESO.
5. Best way to persuade the committee to award your organization the grant (without bribery).
6. How each person in your group will be involved in the presentation to the IESO committee.
7. Type of visual aids that will be used during the presentation.

When the group makes its presentation to the IESO, remember that other groups will also be making presentations. In other words, you're competing directly with those organizations for the funds. As a result, your group's presentation needs to be the most persuasive. While the group is doing strategic planning you should be concerned with answering:

1. What has happened to the population of this species?
2. Why has this species become endangered?
3. What is the future of this species?
4. How have people affected this population?
5. Why is your group's organism more important to save than any of the other groups' organisms?

Resources Available

- the school library
- the public library
- periodicals
- laser disc images
- video tapes
- CompuServe
- computers
- resource books
- reference books

Presentation

When organizations attempt to obtain business or funding, they always try to impress the potential client with a smooth, knowledgeable, clear, and multifaceted presentation. This means they try to present calmly and intelligently, using a variety of methods to persuade the prospective client. Check with your teacher as to what is available and how to use it.

Grading

The project grade will be determined on the following bases: utilization of classroom time, knowledge gained and reported, visual aids, participation in the presentation, creativity, and accuracy of information presented. Each group will also evaluate another group prior to the presentation to the committee. Each person is also responsible for completing the attached planning guide. This form indicates responsibilities and duties of each person within the group.

Planning Guide

Selected Organism ______________________

1. What is your duty or job description? ______________________

2. List all of the tasks you will need to perform to accomplish your job goals.

   a. ______________________

   b. ______________________

   c. ______________________

   d. ______________________

   e. ______________________

3. What is the present state of your species population?

4. What is your understanding as to what has caused this organism to become endangered?

5. As far as you know, how have people affected the population of your organism?

6. What do you foresee as the future of this species?

7. What do you know is currently being done to help your organism?

8. What does your group plan to do with the grant should you win it?

9. What reason do you have for choosing this organism?

10. Give a brief description of your anticipated presentation.

11. What sources do you think you will need?

PEER ASSESSMENT FOR ENDANGERED SPECIES PROJECT

ORGANISM ____________________

DIRECTIONS: Each person is to critique or evaluate another group using the form below. Circle the word or phrase that best describes the other groups' performance based on your observations. Always be positive but also point out potential flaws to the other group.

Was the presentation of the appropriate length?	TOO SHORT	TOO LONG	JUST RIGHT
Did the topic provide good information?	CONTAINED NO INFORMATION	CONTAINED A LITTLE NEW INFORMATION	THERE WAS A LOT OF NEW INFORMATION
Was everyone within the group involved with the presentation?	ONLY A FEW PEOPLE WITHIN THE GROUP WERE INVOLVED IN THE PRESENTATION	ONLY A FEW PEOPLE WITHIN THE GROUP WERE NOT INVOLVED IN THE PRESENTATION	EVERYONE WAS ACTIVELY INVOLVED IN THE PRESENTATION
What was the quality of the visual aid(s)?	VISUAL AIDS DIDN'T EXIST	THE VISU DS COULD HAV D BETTER	THE VISUAL AIDS WERE USED APPROPRIATELY TO IMPROVE AN UNDERSTANDING OF THE PROBLEM
What was the quality of creativity?	NEEDS IMPROVEMENT	TISFACTORY	OUTSTANDING
Were the participants ready and well informed when asked questions?	INDIVIDUALS HAD A LOT OF TROUBLE ANSWERING QUESTIONS	INDIVIDUALS ANSWERED MOST QUESTIONS WITH NO PROBLEMS	INDIVIDUALS ANSWERED ALL QUESTIONS CORRECTLY

On the back of this form place comments that will help the group improve their presentation. In making these recommendations also consider what areas the teacher will be grading.

A–2

Endangered Species Pamphlet

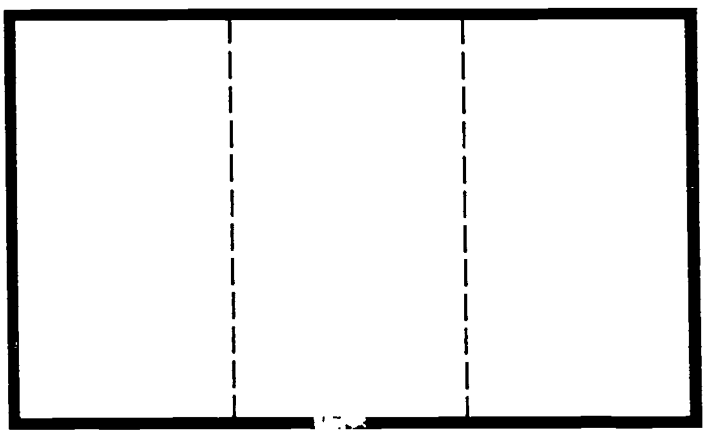
You represent an organization which would like to help save an endangered species. This species may be plant or animal. Your role will be to create an information pamplet from one 8.5" X 11" sheet of typing paper that will try to promote interest in your cause. You want this pamphlet to be as impressive and pleasing to the eye as possible. It must be typewritten or created on a computer and contain information on the following:

1. The common name of the organism.
2. The scientific name of the organism.
3. Where the organism lives (you may want to include a map).
4. Major reasons for the organism being endangered.
5. How many of these organisms are left in the wild.
6. Pictures of the organism.
7. A description of the organism and where it is in the food chain.
8. The life span of the organism.
9. How your organization plans to help the organism.
10. Organizations that are already involved in your crusade.
11. What organizations like yours are presently doing to try and save the organism.

Once again your role as the creator of the pamplet is to try and persuade people to donate money and time in helping your cause, so make this venture as professional looking as possible. (HINT: You don't need to spend money to complete this project and get a good grade.)

Set up of the Pamphlet

The pamphlet should be set up so that it is a tri-fold arrangement. Information should be on both the inside and the outside of the pamphlet. Below is an example of how the pamphlet should be folded.



Grading and Scoring

Categories one through nine above have equal point values. The accuracy of information will be determine for each area and points awarded. Creativity and neatness of the final project will be graded also. Items 10–11 will be awarded extra credit points if multiple organizations are found and addresses given where people can write to obtain more information.

A–3

ENVIRONMENTAL EFFECTS OF AN ORGANISM

LAB

BACKGROUND INFORMATION

Wild yeast organisms are important organisms of decay in ecosystems. They help break down and recycle nutrients for reuse by living things. They can be found especially in rotting fleshy fruits such as apples, grapes, bananas, and oranges which contain large concentrations of simple sugars such as glucose and fructose. Under anaerobic conditions yeast converts the energy stored in the sugar molecules to energy for its life processes by an energy–releasing process called fermentation.

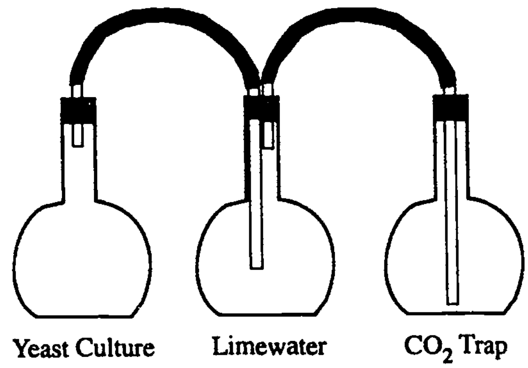
Under favorable conditions yeast reproduces fairly rapidly by asexual reproductive "budding." Therefore, yeast cells can relatively quickly cause foods such as apple cider and orange juice to ferment, unless the juices are refrigerated, and/or chemical preservatives have been added. Some yeast species are also implicated in certain yeast infections in humans.

Yeast organisms represent one of the early examples of biotechnology, since humans have used them for centuries to help make bread, beer, and wine. Today they are being genetically engineered as microscopic "biochemical factories" to help produce certain pharmaceutical molecules such as insulin.

In this activity we will be using yeast organisms to investigate the fermentation process. It will help prepare you for many of the techniques used in chemistry and in BESS 2.

MATERIALS

Setup as shown in the drawing below, activated yeast solution, 400 mL of light molasses solution (approx. 1 part molasses to 9 parts water), limewater solution, water, filter paper, and small beaker.



DAY 1 PROCEDURE

1. Obtain the setup as shown above.
2. Into the middle florence flask place 150 mL of the limewater.
3. Into the last flask place 150 mL of tap water.
4. Into the first flask place 10 mL of the yeast culture and 400 mL of the molasses solution. This solution is the food source for the yeast.
5. Seal all flasks tightly and obtain a piece of tape to label your flask setup. Place your setup where instructed by your teacher.
6. Obtain a piece of filter paper. Go to the balance and record its mass in the appropriate space on the Data Table.
7. Obtain a small beaker, label it with your name, put the filter paper inside, and place it in the drying oven.
8. Enter all other groups' masses for the filter paper on the Data Table. Determine the average mass for the filter paper for the class.

Day 2 Procedure

1. Remove the filter paper from the drying oven and determine its weight again. Record the results on Data Table 2.
2. Record all the other groups' masses on Data Table 2. Determine the average mass of the dried filter paper on Data Table 2.
3. Determine the average mass of filter paper lost by drying. Record this value on Data Table 2.
4. Obtain your lab setup. Swirl and pour your limewater from the middle florence flask into a beaker. If necessary, add a small amount of water to the flask and swirl to remove the last amount of white precipitate.
5. Place 150 mL of fresh limewater into the middle flask and stopper again.
6. Put your setup back in place.
7. Use the filtering technique demonstrated to you by your teacher to collect the white precipitate. BE PATIENT! This does take time.
8. Place your filter paper and filtrate into a marked beaker and place in the drying oven over night.

Day 3 and All Subsequent Days

1. Remove the filter paper from the drying oven and determine its weight again. Record the results on Data Table 3.
2. Obtain your lab setup. Swirl and pour your limewater from the middle florence flask into a beaker. If necessary, add a small amount of water to the flask and swirl to remove the last amount of white precipitate.
3. Place 150 mL of fresh limewater into the middle flask and stopper again.
4. Put your setup back in place.
5. Use the filtering technique demonstrated to you by your teacher to collect the white precipitate. BE PATIENT! This does take time.
6. Place your filter paper and filtrate into a marked beaker and place it in the drying oven over night.

Final Day

Graph the mass of CO_2 by time (in days).

Define

1. aerobic
2. anaerobic
3. fermentation
4. filtrate
5. precipitate

Questions

Anwer all questions in complete sentence form.

1. Describe any activity you observe happening in the flask containing the yeast.
2. Assume that molasses is mostly (or can easily be converted into) glucose ($C_6H_{12}O_6$) and that the yeast cells are using it as food. Predict what will most likely be the products of the breakdown of glucose by yeast.
3. Are conditions inside the flask aerobic or anaerobic? Why?
4. Based on changes in the limewater, what gas might this be?
5. Carefully remove the stopper from the flask, and smell the flask contents. What does it smell like? What chemical may have been produced in the flask?
6. According to your graph, what would eventually happen to the yeast cell population in the flask? Why?
7. Summarize what you have found out about fermentation.
8. What are some beneficial uses of yeast organisms by and for humans?
9. What are some harmful effects of yeast organisms to humans?

B

Reintroduction of *Castor canadensis* to Harveysburg

Introduction

You are a wildlife biologist commissioned by a committee of the Harveysburg Division of Wildlife Management to investigate the feasibility of reintroducing *Castor canadensis* into a habitat that it once occupied. *Castor canadensis* was hunted for its pelt in this area until it was extirpated in 1905. The Harveysburg Division of Wildlife Management has determined that there are eight sites which are potentially good for its reintroduction. Your research literature tells you there are five important factors which will determine the potential success of the reintroduction. *Castor canadensis*:

- Needs to be a minimum of 5 miles away from any human activity.
- Prefers to live in streams or rivers that have a gradient between 2 and 6 feet per mile.
- Predators include wolves, alligators, and cougars.
- Needs unpolluted water in which to live.
- Needs a large supply of deciduous trees which serve as a source of food and building materials for its homes.

In the map room of the Harveysburg Division of Wildlife Management you found four documents which will help you decide which location would be the best for *Castor canadensis*. These documents include: Harveysburg Quadrangle, Harveysburg Summer LandSat Image, Harveysburg Winter LandSat Image, and a Harveysburg Major Wildlife Distribution sheet. The potential sites for reintroduction are indicated by a circled capital letter on each document.

Throughout this entire activity, you will have many resources available to you, including notes, worksheets, textbooks, and dictionaries.

Procedure

STEP 1

As a wildlife biologist you know that a study of this nature must take into account all of the factors mentioned above. You know you must eliminate those sites which are undesirable. This is done by looking at each of the five factors already mentioned.

The first factor you should look at is the distance *Castor canadensis* would be from human activities. Using the Harveysburg Summer LandSat Image, Harveysburg Quadrangle, and the scale provided, determine the distance (in miles for each site) *Castor canadensis* would be from human activity. Record your findings in column 1 of the Data Table on the Report to the Harveysburg Division of Wildlife Management. Then complete **SECTION A** of the report.

STEP 2

Continue to concentrate on the Harveysburg Quadrangle. Recall that *Castor canadensis* prefers to live in streams or rivers that have a gradient between 2 and 6 feet per mile. Determine the gradient for each site showing your computations in **SECTION B** of the report. Measure the gradient using the two contour lines which you can see crossing the river on either side of the site. Record the gradient of each site in column 2 of the Data Table. Complete the remainder of **SECTION B** of the report.

STEP 3

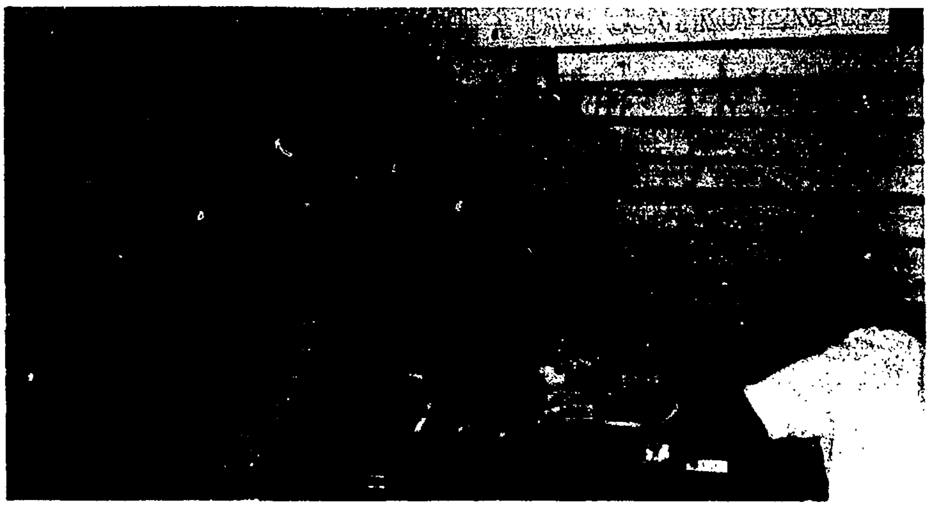
Next you decide to consider predators of *Castor canadensis*. Almost all sites will have predators. One factor to consider when looking at the Harveysburg Major Wildlife Distribution map would be the range of the different kinds of predators. In your study you have determined that wolves have a hunting

range of about a ten mile radius and cougars have a range of about ten miles. Using the Harveysburg Major Wildlife Distribution map and the same scale as found on the Harveysburg Quadrangle, count the number of predator symbols which will interact with *Castor canadensis* at each site. Record this information in column 3 of the Data Table.

STEP 4
Next you decide to investigate those sites which are affected by pollution. *Castor canadensis* is very sensitive to pollution due to human activities. Using the Harveysburg Summer or Winter LandSat Images and the information you have learned through your classroom studies, determine which sites would be eliminated due to pollution. In column 4 of the Data Table indicate if the site contains pollution (yes) or if it is free of pollution (no). Complete **SECTION C** of the report.

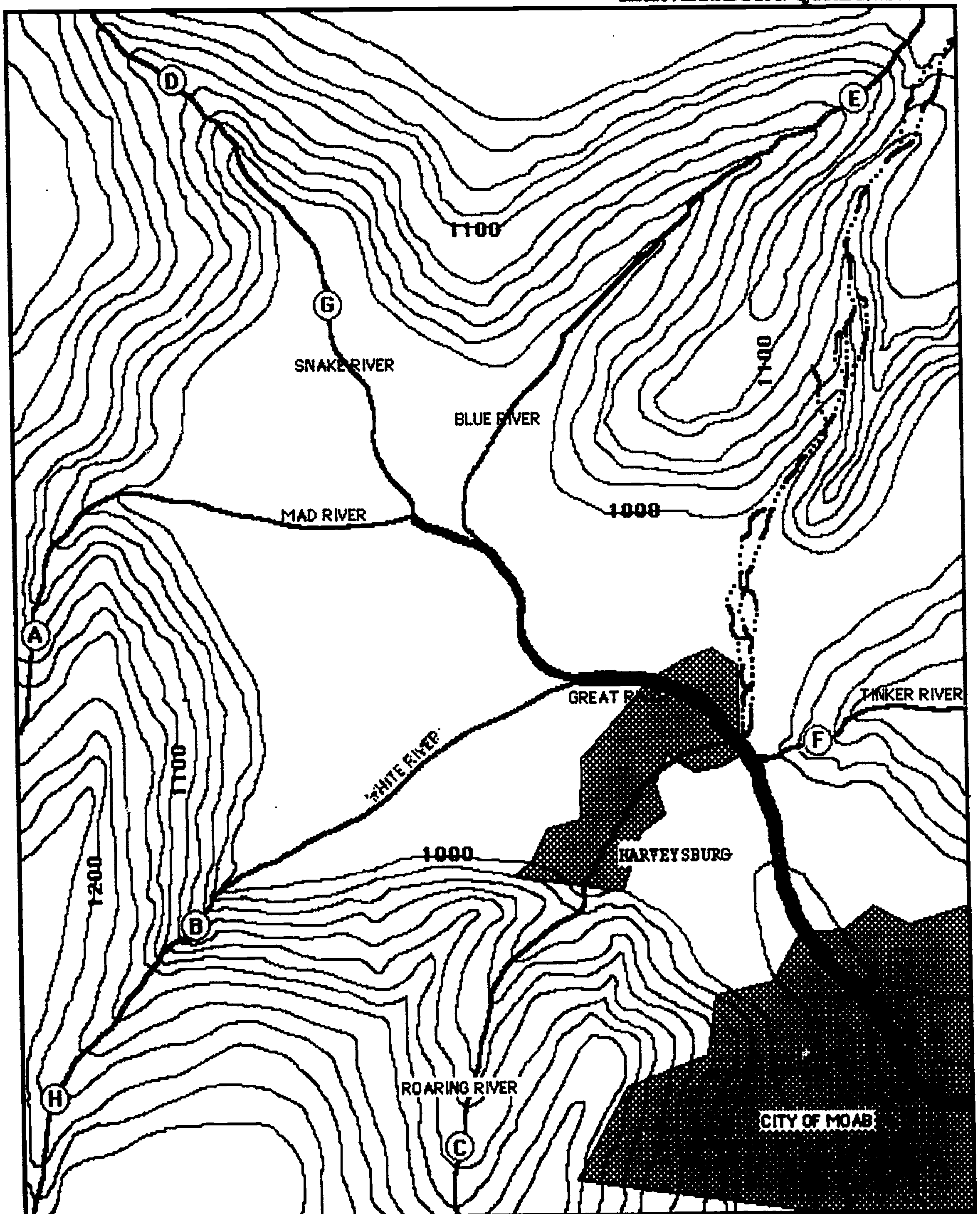
STEP 5
Now consider the last factor, the presence of deciduous forests used by *Castor canadensis* for food and shelter. Using the Summer and Winter Harveysburg LandSat Images, determine if each of the sites would have the necessary deciduous forest for *Castor canadensis*. Record your response (yes or no) in column 5 of the Data Table. Complete **SECTION D** of the report.

Finally with all of this information you find yourself ready to complete the remaining sections of the report to the Division of Wildlife Management.



BESS student groups at Worthington Kilbourne High School work to complete their assessment of the environmental impact of a dam proposed for a site near Worthington, OH.

HARVEYSBURG QUADRANGLE

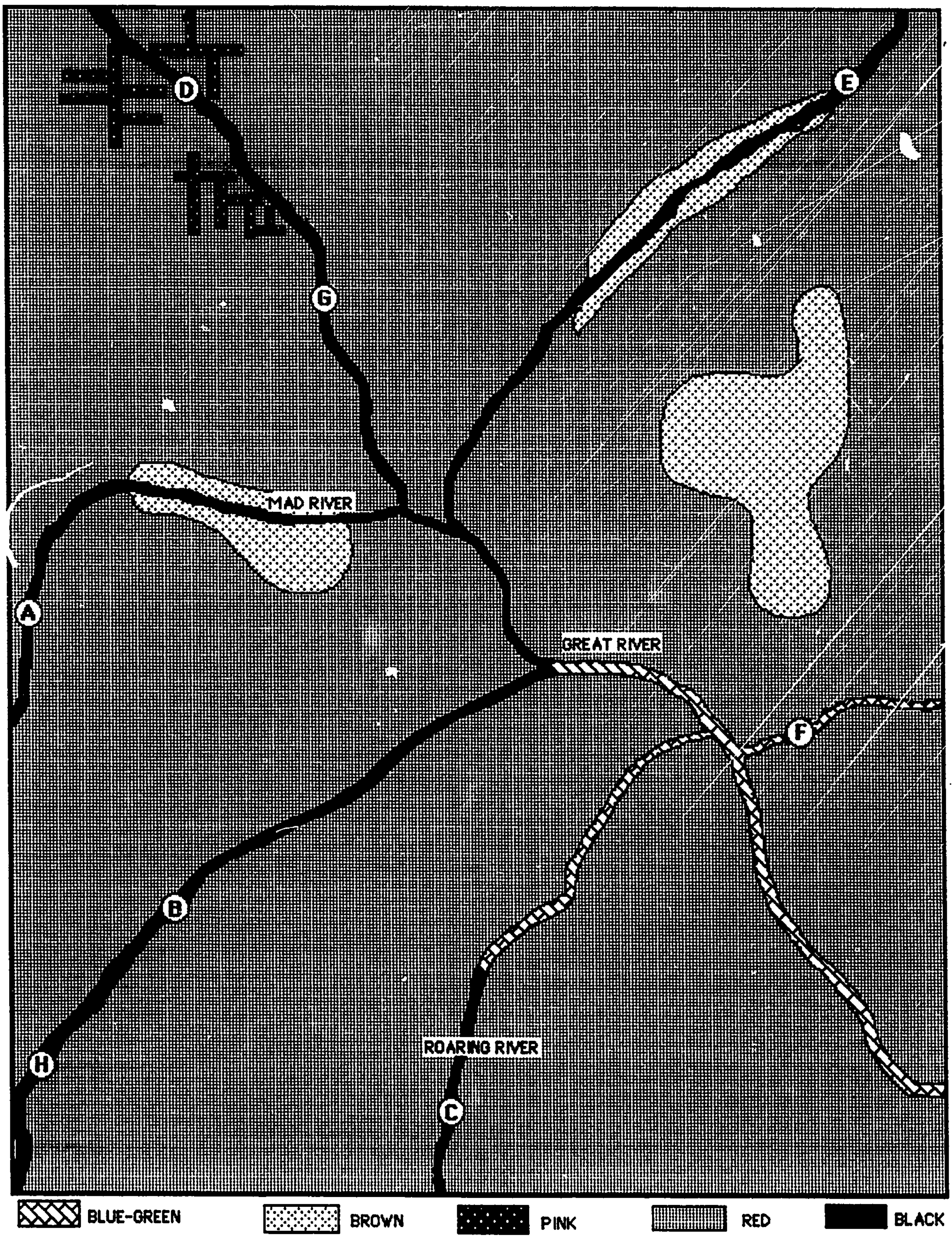


PINK

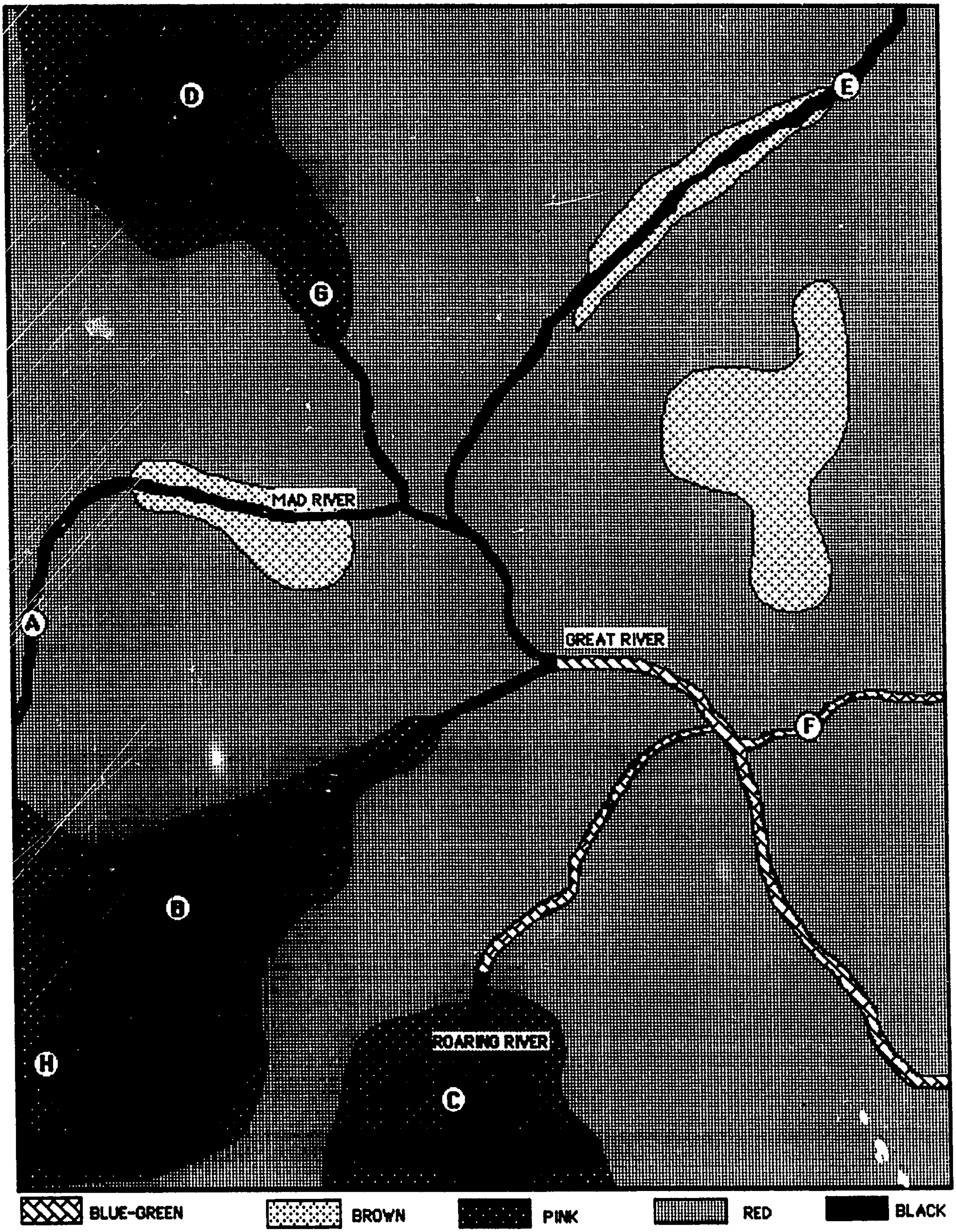
CONTOUR INTERVAL = 20 FEET
1" = 10 MILES

POTENTIAL RE-INTRODUCTION SITE

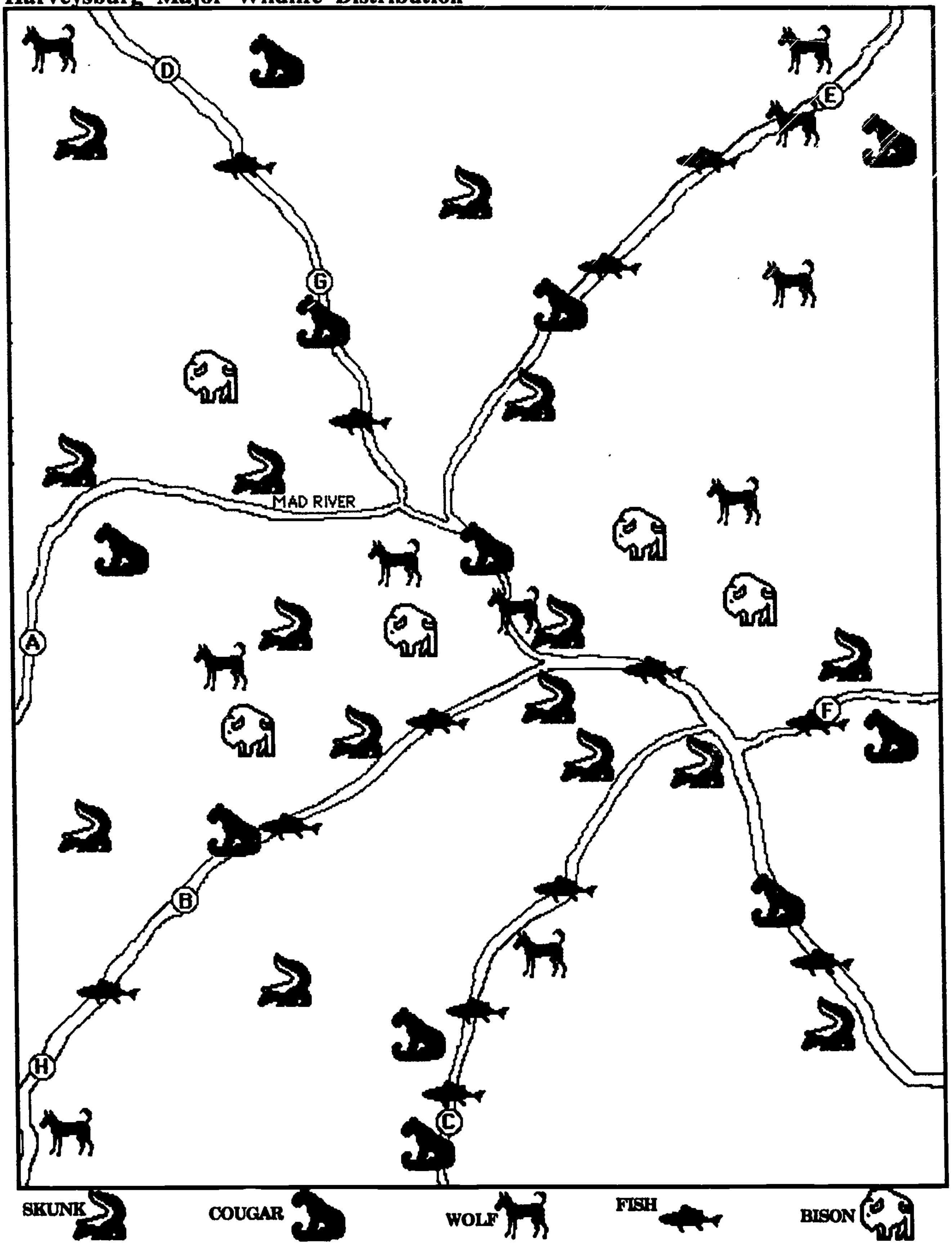
HARVEYSBURG SUMMER LANDSAT IMAGE

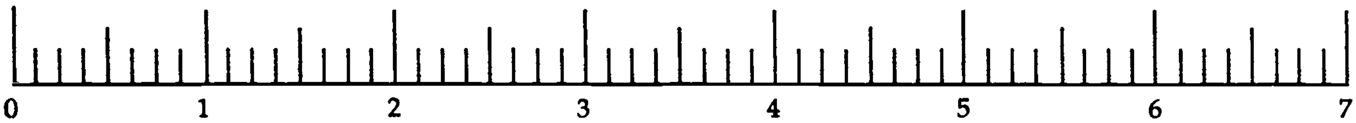


HARVEYSBURG WINTER LANDSAT IMAGE

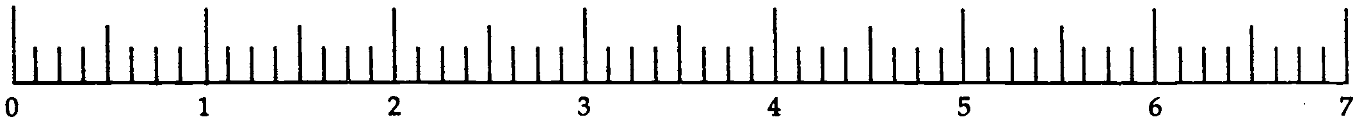


Harveysburg Major Wildlife Distribution





Each Line = 1 Mile 1 Inch = 10 Miles



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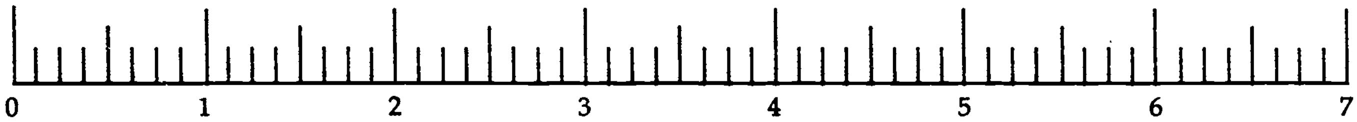

Each Line = 1 Mile 1 Inch = 10 Miles

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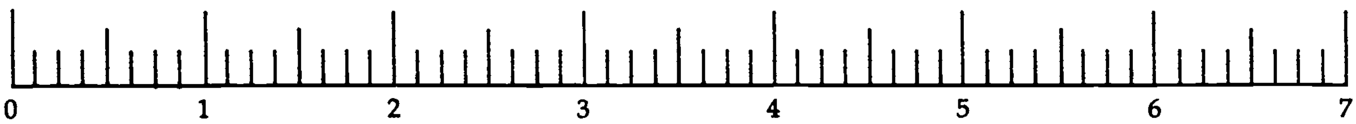
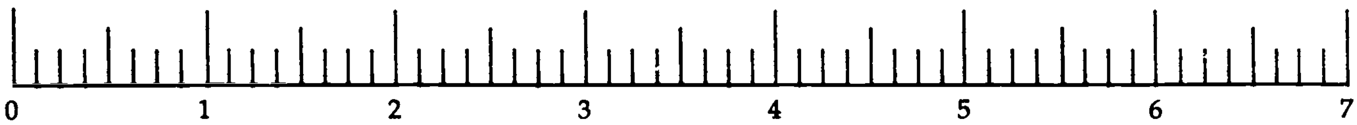
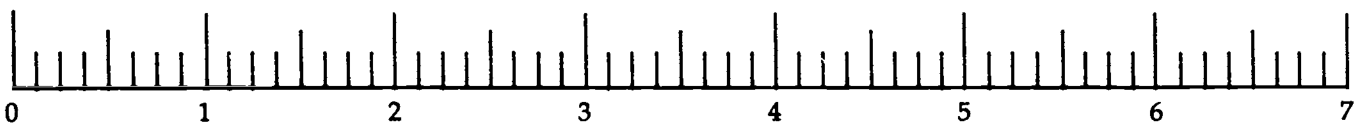


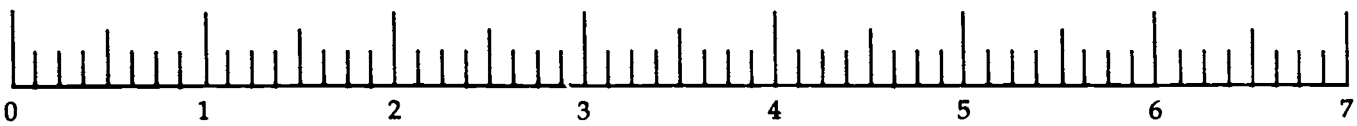
Each Line = 1 Mile 1 Inch = 10 Miles



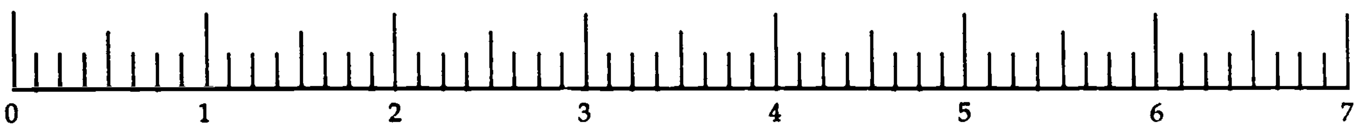
Each Line = 1 Mile 1 Inch = 10 Miles



Each Line = 1 Mile 1 Inch = 10 Miles



Each Line = 1 Mile 1 Inch = 10 Miles



Each Line = 1 Mile 1 Inch = 10 Miles

copy onto transparency film

Reintroduction Report for *Castor canadensis*

Data Table

	Step 1 Distance from Humans	Step 2 Gradient of the Site	Step 3 Number of Predators	Step 4 Presence of Pollution	Step 5 Presence of Deciduous Trees
Site A					
Site B					
Site C					
Site D					
Site E					
Site F					
Site G					
Site H					

Section A

I believe site(s) ____________________ should be eliminated from consideration because of human proximity. My reasoning for this is:

Section B

In my opinion, site(s) should be eliminated from consideration for reintroduction because of failure to meet stream gradient requirements. My calculations are as follows:

Site A Calculations	Site E Calculations
Site B Calculations	Site F Calculations
Site C Calculations	Site G Calculations
Site D Calculations	Site H Calculations

SECTION C

Site(s) ____________ should be eliminated from consideration because of the presence of pollution. This pollution is most likely a result of:

SECTION D

Site(s) ____________ should be eliminated from consideration because of the lack of proper vegetation. More specifically these sites are removed from consideration because:

SECTION E

In my opinion, the best site(s) for reintroduction would be ____________. My reasons for choosing this (these) site(s) are:

After sharing your report with the committee, they posed the following questions:

How many pairs of *Castor canadensis* could be reintroduced to the site(s) considering that one pair requires two miles of undisturbed river in which to live? (Show calculations)

Does the presence of predators necessarily indicate that a site is unsuitable for the reintroduction of *Castor canadensis*? (Explain)

C–1

Weather in Our Lives

Objective

This project is designed to create a better understanding of what weather is and how it affects our daily lives. Every day we get information by watching television, listening to the radio, and reading a newspaper. During this project each class will create its own newspaper composed of several different sections such as the sports, metro, fashion, national, and international news. The class will divide into small groups and determine which sections to include in the newspaper. All members of a group are responsible for doing their part of the newspaper and will be graded accordingly.

It would be a good idea for students to obtain or bring a book such as *Writers, Inc.* with them to class on a daily basis. Books such as *Writers, Inc.* have tips and rules concerning the "how to's" of writing a newspaper article.

Each group will decide upon the articles to be placed in their section. Along with these articles should be found advertisements and comics, such as found in any newspaper. All contributions to the newspaper need to be related to weather directly. Students are advised and encouraged to be creative. The inclusion of art is strongly encouraged.

Evaluation

Students will be graded according to accuracy of factual content, effort/participation, creativity, layout, and format of the project. Students should look more closely at the grading rubric provided.

Important Deadlines

Day 1	Discussion of project
Day 2 & 3	Work on research and developing articles
Day 4	One page rough draft of article due
Day 6, 7, & 8	Complete work on drafts, cartoons, and advertisement
Day 9 & 10	Work on layout of section (cut/paste/printing)
Day 11	Final draft of newspaper due

Concepts Covered in Class

Greenhouse effect/global warming
Ozone depletion
Air pressure systems
Fronts
Weather satellites
Tornadoes
Thunderstorms
Clouds
Storm emergencies
El Niño
Weather related to: food, sports, fashion, business, farming, advertising, and the environment

C–2

How Effective Is a Carbonate Rock at Storing Carbon Dioxide?

Introduction

Carbon dioxide is continuously being released into the atmosphere as the result of many activities which occur within the biosphere. These activities include by–products of respiration, decomposition of organic matter, and the burning of fossil fuels. Because of this, if the carbon dioxide is not re–absorbed and stored someplace, high levels of carbon dioxide in the atmosphere could result in a rise of the global temperature. Scientists estimate that carbon dioxide is the biggest contributor (50%) to the greenhouse shield.

There are three sinks (storage areas) of carbon dioxide that are understood by scientists. First, living organisms, primarily in the form of trees and other plants, store a large amount of carbon dioxide. Second are the oceans of the world. Generally as the amount of carbon dioxide in the atmosphere increases so does the amount in the oceans. The third sink is found in the form of carbonate rocks. The most common type of carbonate rock is limestone. A carbonate rock has the carbonate ion (CO_3^{-2}) present in some form. In this investigation we will be using limestone, which has a general chemical formula of $CaCO_3$. This rock can form many different ways. One method of formation is when calcium oxide found in ocean water reacts with the carbon dioxide found in the atmosphere. This chemical reaction is shown as $CaO + CO_2 \rightarrow CaCO_3$.

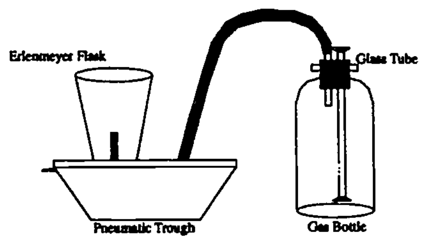
In this investigation you will be reacting limestone with hydrochloric acid. The chemical reaction for this is $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$.

Safety

When using hydrochloric acid make sure you rinse your hands with lots of water. Do not take your goggles off while in the lab. Rinse your hands before you leave the lab. If you get any acid on yourself notify the teacher.

Materials

Gas generating setup, 1 piece of limestone, 250 mL erlenmeyer flask, 1 pneumatic trough, balance, goggles, and 100 mL of 2M HCl.



Procedure

1. Obtain and determine the mass of a piece of limestone. Record this mass on the Data Table.
2. Obtain a gas generating setup as shown in the diagram.
3. Position the setup so that the spout of the pneumatic trough hangs over the sink.
4. Fill the pneumatic trough with water just below the level of the spout.
5. Fill the 250 mL erlenmeyer flask with water. Insert a stopper into the top of the flask so that it may be turned upside down and placed in the pneumatic trough. Remove the stopper. The water should remain inside the flask.
6. One person will need to hold and steady the flask and hose which is placed inside the flask.
7. Place 50 mL of 3M HCl into the gas generating bottle.
8. Carefully place the limestone into the gas collecting bottle and insert the stopper. A chemical reaction between the acid and limestone will immediately begin. Shortly after, bubbles of gas will begin to collect in the erlenmeyer flask. Water will begin coming out of the pneumatic trough spout.
9. Collect 200 mL of the gas in the flask.
10. When 200 mL have been collected immediately stop the chemical reaction by removing the stopper from the gas generating bottle, pouring the acid down the drain, and flushing the limestone with lots of water.

11. Remove the piece of rinsed limestone from the gas collecting bottle and dry it.
12. Determine its new mass. Record this mass on the Data Table.
13. When you're done with lab put everything back where it came from.

Data Table

1. Initial mass of limestone	
2. Final mass of limestone	
3. Mass loss through chemical reaction	
4. Volume of gas collected	
5. Volume of gas generated/gram of limestone (#3 + #4)	
6. Mass of gas/liter (experimental value) [#3 + #4 (in liters)]	
7. Accepted value	1.96 g/L
8. Error (#6–#7 or #7–#6)	
9. Percentage error [(#8 + #7) x 100]	

Questions

Answer all questions in complete sentence form, show all work for questions using mathematical calculations and label answers.

1. What was the gas produced as a result of the chemical reaction?

2. How many milliliters of the gas could be produced from one ton of limestone using this method?

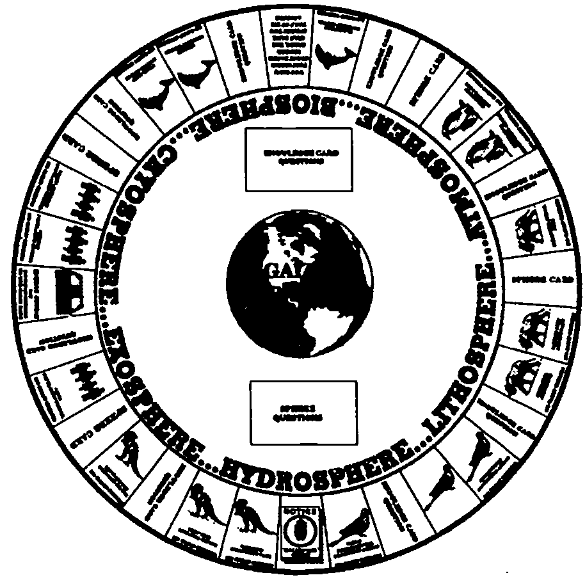
3. Would a silicate rock such as quartz (SiO_2) be considered a "sink" for carbon dioxide? Explain.

4. In the distant geologic past there were times when the amount of atmospheric carbon dioxide was very low. Explain what implications this would have for the formation of limestone.

5. Compare the accepted value and the experimental value for the mass/L. What could account for your error?

D-1

THE GAIAN GAME
TEACHER RESOURCE GUIDE



OBJECTIVES OF THE GAME

The purpose of this activity is to become more aware of many of the environmental and social problems associated with use of our natural resources. The game also tries to foster an understanding of the interconnections of our problems and those of Earth.

GAME PREPARATIONS

1. This activity requires assembly. The game board (above) consists of nine pieces of paper which need to be taped together to make a master. Best results are obtained if this master is then taken to a commercial copier or printer where it can be duplicated in full size on one sheet of paper. It would also be a good idea to laminate the game boards so they will withstand the day–to–day use found in the classroom.

2. Along with the game board the Gaian Credits (money), Knowledge Cards (two–sided copies), Sphere Cards (two–sided copies), and Property Cards must also be duplicated for each game board used in the classroom. Making the different denominations of Gaian Credits is helpful but not necessary.

3. The game is best played with three teams of two players at each game board. This allows for maximum interaction between participants. Other combinations of teams will also work.

4. Game pieces (or tokens) and a pair of dice must be purchased for each game board.

5. Blank pages for additional questions are also included.

PURPOSE OF THE GAME

The purpose of this game is for the individual to become more aware of some of the impacts that he/she has on the Earth. The game will also help to demonstrate how the human population has had an impact on the Earth.

CREDITS

ecoHOME. 1992. Anna Kruger. Avon Books, A division of The Hearst Corporation, 1350 Avenue of the Americas, New York, NY, 10019.

50 Simple Things You Can Do To Save The Earth. 1989. Earthworks Press, Box 25, 1400 Shattuck Avenue, Berkeley, CA 94709.

The Whole Earth Quiz Book. 1991. Bill Alder Jr., Quill William Morrow, Permissions Department, William Morrow and Company, Inc., 105 Madison Avenue, New York, NY 10016.

NOTE: **Masters of the game materials are not included in this Resource Guide. They can be obtained from the Earth Systems Education Program Office.**

The Gaian Game Rules & Instructions

To Begin The game is designed to be played by three or four teams of two players each with each team having one game piece. The purpose is to have team members discuss and answer questions presented to the team. Teams will begin on the square called "IT'S A NEW YEAR" and move around the game board in a clockwise direction, using the dice to determine how many squares they will move.

Each team will be given the following quantities of GAIAN CREDITS (money) to begin the game:

5 each—1 GAIAN CREDIT
5 each—5 GAIAN CREDITS
5each—10 GAIAN CREDITS
5 each—20 GAIAN CREDITS
5 each—50 GAIAN CREDITS
4 each—100 GAIAN CREDITS
4 each—500 GAIAN CREDITS

Banker One individual (participant) will act as the banker for the duration of the game. This person will be in charge of the extra cash. He/she will: 1) receive payment for the purchase of properties, and 2) make payments to teams for Sphere Card actions. The Banker has no duties associated with the Gaian Bank.

Gaian Bank The Gaian Bank is the center of the game board. It is the place where Gaian Credits from the team will be deposited for: 1) Energy Taxes, 2) incorrect answers to Knowledge questions, and 3) Sphere Card actions.

Movement If a team rolls doubles they may roll and move again. If they roll 3 doubles in a row they are declared energy guzzlers for that turn and will pay the Gaian Bank (center of the game board) 100 Gaian Credits. They will also lose their next turn.

Property Cards Teams may become owners of properties by paying the banker the number of Gaian Credits shown on the game board. If another team lands on an already owned property, that team must pay the team which owns the property the individual membership number of Gaian Credits shown on the property card.

If a team manages to purchase all properties of the same kind (shown as penguins, dinosaurs, dolphins, etc.) that team may charge the group a membership fee.

Knowledge Cards When a team lands on a Knowledge Card square another team will pick up a Knowledge Card from the pile and read the question and possible answers to the team which landed on the square. At least three possible answers are given for each question. Once the question and possible answers are read, the team must pick one of the answers. The team which read the card will tell them the correct answer and the accompanying explanation.

If the team answers the question correctly, then nothing happens. If they answer it incorrectly, they donate 10 Gaian Credits to the Gaian Bank.

Sphere Cards When a team lands on a Sphere Card square they will pick up the card and read it aloud. If they are to receive Gaian Credits it will come from the banker. If they are to pay Gaian Credits it will go to the Gaian Bank.

Earthly Deed Square If a team lands on this square they will receive one-half of the number of Gaian Credits in the Gaian Bank.

Energy Tax Square If a team lands on this square they will pay 10% of their Gaian Credits to the Gaian Bank.

It's A New Year Square When a team passes this square they will receive 200 Gaian Credits.

Trading Teams may make trades of properties which may or may not include Gaian Credits.

Winning A team is declared the winner if by the end of the time period they have the most Gaian Credits (including the original cost of any properties the team owns).

D-2

MICROORGANISMS IN THE SCHOOL ENVIRONMENT

INTRODUCTION
We are surrounded by many microorganisms in our environment. Fortunately, most of them are not pathogens or allergens. Molds release many spores which become airborne. Bacteria and yeasts can become airb ~ie and widely distributed also.

PURPOSE
This activity will compare the types and relative abundance of certain microorganisms in various school locations.

PROCEDURE
1. Obtain one sterile nutrient–agar plate for your 2–student team. DO NOT OPEN IT UNTIL THE PROPER TIME!

2. Decide on a location within the school building where you would like to expose the sterile nutrient–agar plate to find out the kinds and relative numbers of microorganisms.

3. When you are in the location you have chosen, take off the cover of the petri dish and set it in position. Stay with your plate but stand back at least 8 feet from the open dish. *Why?*

   Expose the nutrient–agar surface to the air for **exactly 10 minutes.** *Why?*

   It will be helpful to have a watch or have one partner check a nearby clock for the proper exposure time.

4. See instructions below for what to do upon returning.

RESTRICTIONS AND GUIDELINES

a. Only one team per location
b. Use good public relation skills (i.e. don't barge in on classes in session unless you know the teacher very well, and get his/her OK. If you go to places such as offices, library, cafeteria area, etc. explain what you are doing in the activity and request permission of the person in charge.
c. While in the hallways…be quiet and DON'T DISRUPT CLASSES!
d. No boys in girls restrooms and vice versa!

UPON RETURNING

1. Invert your team's exposed plate.
2. Use 2 small pieces of tape to secure the top and bottom.
3. Label you dish.
4. Incubate (inverted) at room temperature in a location where there is no direct sunlight.
5. Observe each day for about a week. Record your observations.
6. At the end of the week, compare the dishes that were exposed at different locations. Are there differences in the amount of growth or in the types of organisms?
7. Explain the possible causes of any differences you found.

EXTENSIONS

1. You might collect two samples from each location. Then place one where direct sunlight will fall on it during incubation and the other where it will be dark all of the time. Note differences.

2. Collect microorganisms from surfaces in each of the school locations. Use cotton swabs soaked with sterilized water. Observe differences between locations. Also differences between air and surface at each location

E-1

Biome Booth

Introduction

Over the next week a group of students will conduct an in-depth investigation of a biome.

You will do this by creating a booth that contains:

1. Information that appropriately answers all the questions on the Biome Booth Organizer.
2. Other relevant information from your biome that your group thinks is important enough to share with the class.
3. Creative and artistic visual aids.
4. Construction of a climatogram for the biome.
5. A receipe that represents a human culture living within or from your biome. (Extra credit for an actual serving of your receipe.)

Sources of Information Which May Be Helpful in Constructing Your Booth

- the public library
- the school library
- any in-class materials
- laser disc images
- magazines from home or from within the room
- poster board and markers
- resource books found in the room

Presentation

The presentation part of this project will be handled as a "Travel Show." You will act as travel agents trying to entice people to visit your biome. You will obviously try to present your biome in an upbeat and inviting display. Point out the positive things a person could do within your biome. Try to find what other resorts, vacation attractions, outdoor or leisure activities are already offered that entice people to visit your biome. Four groups will present their booths each day. Students will take a tour of each booth during the class period. The travel agents (presenters) will be available to answer questions the class may have about their booth.

Booths **MUST** be designed so they can present themselves to individuals in the class. **Do not simply go through and answer the questions from the worksheet in order.** Make the booth interesting and informative.

Grading

The project grade will be determined on the following areas: knowledge gained and reported, participation in project, creativity, visual aids, accuracy of information presented in the booth, and utilization of classroom research time. Each group will also be evaluated on a peer assessment sheet by the rest of the class.

Biomes to Choose from:

- DESERT
- TUNDRA
- TROPICAL RAIN FOREST
- SAVANNA
- GRASSLANDS
- TAIGA
- CHAPARRAL
- DECIDUOUS FOREST
- TEMPERATE RAIN FOREST (PACIFIC NORTHWEST)
- PERMANENT ICE OR ARCTIC
- RUNNING FRESH WATER
- STANDING FRESH WATER
- MOUNTAIN OR ALPINE

BIOME BOOTH ORGANIZER

ABIOTIC FACTORS OF THE BIOME

1. In what part of the world is this biome found?
2. What are the average monthly amounts of precipitation for this biome?
3. What are the average monthly temperatures for this biome?
4. Name and describe any geologic events that occur in this biome?
5. What is the soil like in this biome? What is it composed of? What is the name for this soil type? What is the soil rich in or what does it lack?
6. What is weather like in this biome?
7. What are the major geologic features of this biome?

BIOTIC FACTORS OF THE BIOME

1. What are the dominant animal forms?
2. What are the dominant plant forms?
3. What life forms are endangered?
4. Are there any environmental events occurring in this biome that will affect life forms? If so, then describe the problems.
5. What factors influence the appearance of the life forms in this biome?
6. How has life changed in the region represented by this biome?
7. What are examples of unique adaptations of organisms found in this biome?

Cultural Influences

1. What are the major cultural characteristics of this biome?

2. Is this biome unique to one area of the world? Be able to explain your answer.

3. How have humans shaped or altered this biome?

4. What are the human populations of the countries in this biome like? Are they stable, aging and declining, or young and growing? How do you know?

5. What are the mortality rates of these countries like?

7. What kind of crops do these people grow?

8. What are the major sources of nutrition (food) for these people? List them. Do citizens of these countries consume the same food as we do? If not, why do they consume other foods?

Individual Role and Duties Within the Activity

What is Your Job Title in this Activity?

In the space below give at least 3 different tasks which you will need to perform to fulfill your duties.

1.
2.
3.
4.
5.

List All Resources Used For Your Part of the Project (minimum of four must be used)

1.
2.
3.
4.
5.
6.

Biome Booth Project Grading

BIOME BOOTH ORGANIZER	–very little information provided –no job description	–organizer turned in, but sketchy information presented in it –little supplemental material	–organizer completed; great detail provided –many notes and resources turned in
PARTICIPATION IN PROJECT	–student contributed very little to group	–showed interest, but wasn't focused	–was a group leader –student was self–directed
KNOWLEDGE GAINED & REPORTED (FROM QUESTIONS BELOW AND INFORMATION FOUND IN BOOTH)	–student did not have a firm grasp of material	–student seemed to know material, but stumbled when questioned	–student had a firm grasp of information –very few errors of information
VISUAL AID	–pictures did not correspond to subject	–pictures always corresponded to subject –some information hard to read because of size –food extra credit	–pictures always corresponded to subject –visually appealing –all information easy to read –recipe present
ACCURACY OF BOOTH INFORMATION	–many inaccuracies of information –large quantities of information missing	–occasionally reported inaccurate information –occasional omission of required information	–was able to answer questions easily –all required information was present

_____ 1. What is a biome?

_____ 2. What factors makes your biome unique or different from the other biomes?

_____ 3. Why do different biomes occupy different regions?

_____ 4. From a human's view, explain why it is advantageous to have a large number of different kinds of biomes in the world.

_____ 5. The bumper sticker says "Have you thanked a biome today?" Give some reasons why you should.

_____ 6. Assuming that humans had the technology to live "comfortably" in any biome, in which of the biomes would you most want to live?

_____ 7. Why don't you find a rain forest type biome in Ohio?

_____ 8. Give a <u>specific</u> example of how humans have affected a biome.

_____ 9. If only the rain forest biome existed, how would this effect the rest of the world?

_____ 10. Which biome is "most important"? Why do you believe this?

E-2

Soil Analysis

Introduction

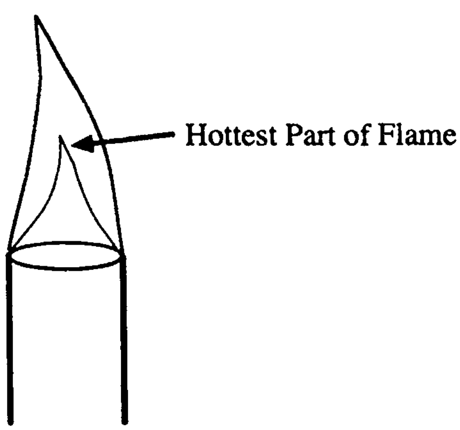
Plants grow, shed leaves and blossoms, die and fall to the ground. Dead plant material decays and forms humus. Humus mixes with the soil and enriches it by replacing nutrients taken out of the soil by growing plants. In this activity you will determine the percentage of humus in a sample of soil

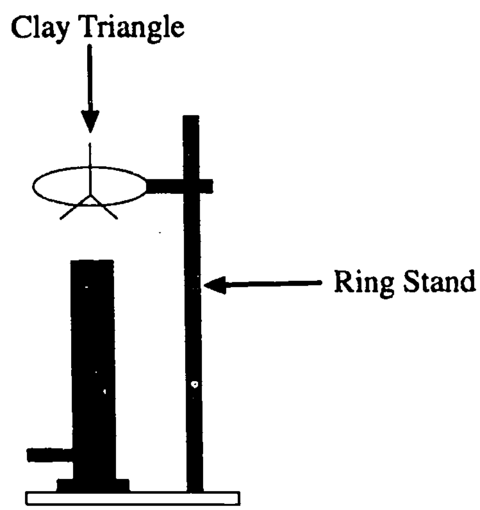
Equipment

- crucible
- clay triangle
- balance
- ring stand
- crucible tongs
- sample of soil
- bunsen burner

Procedure

1. Determine the mass of the crucible and the crucible lid to the nearest 0.01 grams. Record the mass in the Data Table.
2. Fill the crucible about half full with your soil sample. Record the mass of the soil sample and crucible in the Data Table.
3. Record the mass of the soil sample in the Data Table.
4. Place the crucible in the clay triangle setup shown in the diagram. Heat the contents of the crucible for 20 minutes in the hottest part (see diagram) of the bunsen burner flame. After a short time of heating, the crucible should glow red hot. You may notice smoke and flames coming out of your curcible, this is OK.
5. Turn off the burner and allow the crucible to cool for 5 minutes.
6. Once the crucible has cooled, weigh it and record its new mass. Record its new mass in the Data Table.
7. Observe the soil sample for any change in its appearance.
8. Record the same Data Table information from two other groups and record their information in the columns Group 1 and Group 2.





Data Table

	Your soil sample	Group 1	Group 2
1. Mass of crucible			
2. Mass of crucible and soil sample			
3. Mass of soil sample (#1 - #2)			
4. Mass of crucible and soil sample after heating			
5. Mass of soil sample after heating (#4 - #1)			
6. Mass of humus (#4 - #5)			
7. Percentage of humus in soil sample (#6/#3 x 100%)			

Questions

Answer the following questions in complete sentences.

1. Describe the contents of the crucible after the heating has been completed. How has it changed compared to before the heating?

2. What is humus? Why did it disappear during heating?

3. Why would someone add peat moss to their garden for flower beds?

4. With regards to the amount of humus, which type would be more desirable, soil with a high concentration or soil with a low concentration? Explain your answer.

5. How does your data compare with the data you have recorded from other groups in your class.

F

Culminating Activity

Introduction

During the next two weeks you will be involved in producing a magazine. This magazine will focus on many of the topics that were part of the curriculum. These topics are extensions of the curriculum. Each person will perform two duties during the project. These duties are listed in the two sections below. As a result of this activity, each student will leave this course with a magazine containing articles representative of the curriculum.

Duties for Part One (everyone)

Your role during the first part of this activity is to act as a research journalist for the magazine. Students will work by themselves to investigate one of the topics. Each individual will present the information which was researched in a concise article. The articles shcuid deal with any one of the topics on the following page. Or if you would like to investigate another topic that deals with the curriculum, discuss it with the teacher for approval.

You're in total control of what will go into the final article. The article must point out, or bring to light, the problems associated with the topic and draw attention to the positive things that are being done to improve, control, combat, or prevent the problem from getting any worse.

Article criteria

1. It must be typed.
2. It must be a minimum of 200 words and a maximum of 400 words.
3. Journalist name(s) must appear on the top center directly below the title of the article.
4. The article may be humorous, but it must be in good taste and present accurate information.

Your article topic will determine what department you'll be working in. No department may have more than 6 members.

Duties for Part Two (everyone)

After each group has completed the assignment of typing their article, the groups will further divide themselves into groups to complete the following jobs.

Editorial Job

1. 1 or 2 people
2. Proof read and organize the sequence of articles for the department.
3. Place the articles, advertisements, poetry, and artwork in the PageMaker program.

Non-Editorial Jobs

1. The rest of the department members belong to this group.
2. Advertisement:
   a. each person creates an environmental ad to go into the department's section of the magazine;
   b the advertisement may not exceed 3.5 inches high by 3.5 inches wide.
3. Any person (not editors) may write an editorial letter which meets the following criteria:
   a. is positive;
   b. deals with one of the following topics:
      - man's impact on the environment;
      - what man can do to improve things;
      - what kinds of things man is doing now to improve our environment;
   c. no more than 100 words.
4. Cartoons or art:
   a. black and white line drawings;
   b. must pertain to subject material appropriate for the curriculum.
5. Poetry.

Magazine Departments

[illegible]

- Uses of remote sensing
- Air and water quality
- Toxic wastes
- Hunting
- Alternative energy sources
- Natural resource problems
- Pesticides and organic farming
- Acid rain
- Water quality
- Droughts
- Recycling
- Environmental stewardship
- Endangered species
- Oil spills
- Results of pesticide use
- Food additives
- Poaching
- Zoo questions

The World Department

- Systems and cycles
- Population explosion
- Wildlife trade (exotic pets)
- Ozone depletion
- Rain forests
- Habitat destruction
- Environmental organizations
- Global warming
- Deforestation
- Soil Conservation
- Desertification
- Weather forecasting and how its changed our lives?

Grading Criteria for the Project

The grading of this project will be multi–faceted. Each person will be graded according to:

1. Research time utilization.
2. Participation in the project.
3. Creativity.
4. Final project appearance.
5. Accuracy and quality.
6. Editoral/advertisement/letter duties (week 2).
7. Knowledge gained.
8. Meeting the article criteria listed above.

Time Line for the Magazine

Day 1	Discussion of magazine project and assignment of articles.
Day 2	School library research time (meet in library).
Day 3	School library research time and write article (meet in library).
Day 4	Complete research and write article.
Day 5	Type article.
Day 6	Type article.
Day 7	Type article.
Day 8	Complete article.
Day 9	Editorial and advertisement duties.
Day 10	Editorial and advertisement duties
Day 11	Complete all duties and wrap up project.

Magazine Cover Contest

A cover for the magazine must designed. The winner of the contest will receive a prize. The cover designs will be judged by faculty members. All contestants must turn their entry into the teacher by the date assigned. Only one person may work on an entry. The entry should meet the following criteria:

1. Be on an 8.5 by 11 inch sheet of paper.
2. Be black and white (no other colors).
3. A title for the magazine.
4. Black pen should be used over lines on the artwork.

G–1

Microcosm Lab and Analysis

Procedure

Put 400 mL of pond water in a beaker and add 5 mL or 100 drops of bromthymol blue indicator. Swirl the mixture to get a uniform blue color. The indicator will not harm any living organisms.

Label and number sixteen culture tubes following the system given in the Data Table. Add 5 grams of gravel to those tubes which should receive gravel (i.e. tubes # 2, 5, 6, and 8). Next, add 15 mL of pond water to each tube. Select eight healthy shoots of an aquatic plant, each 8 cm in length, and all of the same vigor. Also, select eight healthy snails, all of approximately the same size.

Put no organisms into tubes 1 and 2. Place a sprig of the aquatic plant into tubes 3, 5, 7, and 8. Put a snail into tubes 4, 6, 7, and 8. Place caps or stoppers into the tubes and tighten securely.

On the Data Table for day 1, record the starting condition for all 16 tubes, noting the color and condition of the water and the vigor and behavior of the organisms. Be specific (i.e. note the location of the snail in the test tube, the color of the plant, etc.). Wrap aluminum foil around each of the eight test tubes labeled with a **D**, so that no light enters. Place all the tubes in a well lighted place, but out of direct sunlight. (The tubes should be lighted 24 hours a day.)

Exhale through a straw placed into the bromthymol blue water remaining in the beaker. Continue exhaling for about 1 minute. What do you observe?

Examine the tubes daily for four more consecutive days recording your observations in the Data Table. Do not interpret your observations. Record just what you see! Note the water color and condition of the living organisms. Be sure to securely re–wrap all of the **D** tubes with foil to block out the light.

Use your data table to answer the analysis questions.

Hypothesis

Based on your current knowledge, write down what you think will happen in each test tube. Provide a logical explanation for each of your hypotheses.

Microcosm Data Table

L D (circle)

Date	1 Water	2 Water Gravel	3 Water Plant	4 Water Animal	5 Water Gravel Plant	6 Water Gravel Animal	7 Water Plant Animal	8 Water Gravel Plant Animal

235

Analysis

1. (a) What was the result of blowing exhaled air into the bromthymol blue water?

   (b) How would you explain this? List at least 3 possible factors that could cause the observed change.

   (c) Which of these factors actually caused the change and why?

2. What makes tubes L8 and D8 a system?

3. (a) What are the subsystems in tubes L8 and D8?

   (b) Compare the subsystems in both tubes. How are they similar? How are they different?

4. How do the subsystems in tubes L8 and D8 change through time?

5. What are the inputs and outputs of energy, matter, services, etc. in tubes L8 and D8?

L8

	Inputs	Outputs
Energy		
Matter		
Services		

D8

	Inputs	Outputs
Energy		
Matter		
Services		

6. Looking at all the tubes, what are the results of changes or disruptions of these inputs and outputs on the system?

7. Give an example of a positive feedback in tube L8.

8. Give an example of a negative feedback in tube L8.

9. Give at least 2 ways in which this closed mini–ecosystem is similar to the whole Earth system.

10. Give at least 2 ways in which this closed mini–ecosystem is different from the whole Earth system.

11. Do you think that these systems could last for a period of time substantially longer than a week. Explain your reasoning for each of the following tubes:

(a) L3

(b) L4

(c) L5

(d) L6

(e) L7

(f) L8

12. Develop a diagram of the interactions between the atmosphere, biosphere, hydrosphere, lithosphere, and exosphere in your microcosm, using information from tubes L8 and D8. Use arrows to show interactions and give a brief explanation of the interaction on each arrow.

BESS student group at Worthington Kilbourne High School working on a simulation.

G-2

Create an Ecosystem

Introduction

The interrelationships within an ecosystem are among the least understood by scientists. Ecosystems include many complex factors, both biotic and abiotic. Because of this complexity, ecosystems are difficult to study. It is even more difficult to reproduce an ecosystem within a laboratory environment. However, it will be your task to design an enclosed ecosystem, incorporating what you learned over the course of the Microcosm Lab, as well as information on ecosystems found in the biology, environmental science, and Earth science books in the reference library at the rear of our classroom. See what you can learn about successful terrarium, vivarium, and aquarium construction and maintenance by consulting resources in libraries. Read about the Biosphere II project, too.

Starting Point

The components of your proposed ecosystem need to fit into the carboy (plastic jug) that you see in front of the room. The carboy will not be cut open in order to place the parts of your proposed ecosystem within it. Whatever you want to put into the system must fit in through the narrow neck! Be creative! Your proposed ecosystem could either be aquatic or terrestrial. Think of the producers, consumers, and decomposers that would be necessary to sustain your ecosystem. What ratio of these organisms would be most appropriate in order to sustain the ecosystem for the longest period of time? Should there be more producers or consumers? What about decomposers? Your system will be sealed and the only input after closure will be light (either natural or artificial).

The Actual Design

We will share individual ideas and come up with a classroom effort in an attempt to design a closed ecosystem. We will then spend several days rounding up the materials required to execute the design and actually set up the system. Once we set up the system, we will monitor the progress of our closed ecosystem on a daily basis and maintain records to be kept as part of your notebook. You will be asked to periodically evaluate the design of our closed ecosystem, and offer suggestions for potential improvement in the system.

Your Proposed Design

Be specific with the details! A sketch or drawing would help! The greater the detail the better!

BESS teachers discussing their program with educators from Russia.

CELL MODEL RUBRIC

The maximum number of extra credit points this effort is worth is 30.

	0	1	2	3	4	5
Authenticity of Model	0 Poor	1	2	3	4	5 Excellent
Creativity	0 Boring	1	2	3	4	5 Innovative
Aesthetics	0 Sloppily executed	1	2	3	4	5 Neat
Usability	0 Can't figure it out	1	2	3	4	5 Clearly labelled
Originality of Design	0 Not a novel approach	1	2	3	4	5 Neat idea!
Overall Effort	0 Just thrown together	1	2	3	4	5 A lot of work!

Total ______________

CELL MODEL RUBRIC

The maximum number of extra credit points this effort is worth is 30.

	0	1	2	3	4	5
Authenticity of Model	0 Poor	1	2	3	4	5 Excellent
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Originality of Design	0 Not a novel approach	1	2	3	4	5 Neat idea!
Overall Effort	0 Just thrown together	1	2	3	4	5 A lot of work!

Total ______________

11

Cell Organelle Project

Organelle assigned: ________________

Phone Number: ________________

Group members: ________________

____

____

To complete this project, your group needs to accomplish the following by the assigned date:

1. Read the xeroxed copy of the introduction on the organelle that was given to you.
2. Use resources available to you in the classroom.
3. Use resources available in the library.
4. Consider going to the public library to utilize its resources.
5. Consider using an on-line database like CompuServe or Prodigy.
6. Write a five page, double-spaced paper on your organelle using at least five references. Make sure that your paper has a complete bibliography. Follow *Writers, Inc.* for the format for your bibliography. The paper should be done using a word processing program on the computer.
7. Prepare a display for your organelle, a poster, a model, or some other visual.
8. Prepare a lesson on your organelle for presentation to the class.

In completing this project, you should address the following questions:

1. What is the basic structure of your organelle?
2. Where is it located in the cell?
3. Is your organelle found in both plant and animal cells?
4. What processes take place in your organelle?
5. Why is your organelle important to the cell?
6. How is your organelle related to other organelles in the cell?
7. What does your organelle look like?

Suggestions

1. Your lesson needs to provide the class with the basic information on your organelle outlined above.
2. You will be evaluated by your co-workers for your contributions to the group. Your fellow class members will evaluate your display and your lesson. Your performance will be evaluated in all areas: group participation, display, lesson, and written report.

Organelle Trade Show

You will collaboratively develop a report and a display on the organelle listed above. Both the report and the display are due on the same day at the beginning of the class period. The visual display should provide information on the organelle, e.g. where it is found, what it does, why it is important, who discovered it, how it was discovered, its structure, etc., as well as an attractive visual (poster, drawing, model, transparency). The paper and the display should focus on why your particular organelle is indispensable to the proper operation of the cell as a system. The display should allow other students to quickly learn about the importance of the organelle by taking notes on your work. Your report should be done on a word processor.

Your evaluation will be based upon: (1) the overall appearance of the display, (2) the content of the paper, (3) the style of the paper, (4) your partner's evaluation of your effort, (5) the reaction of the class to your display. You will have some time to research your organelle during class and you will also have access to the computer for word processing your report. I would highly recommend that you have someone proofread your report.

ORGANELLE TRADE SHOW

PEER ASSESSMENT

Instructions

Please take some time to honestly evaluate the work of your fellow group members. Think carefully before responding and use the following rating scale:

5 — Outstanding
4 — Very good
3 — OK; Adequate
2 — Could have done better
1 — Didn't measure up

Name of group member: ____________________

Participation in planning: ____________

Participation in research: ____________

Creative input: ____________

Contributed materials: ____________

Showed interest in project: ____________

Did what he/she promised: ____________

Made effort to work cooperatively: ____________

The best display in the class was made by :

____

We could have made our display better by :

____

____

____

____

____

____

____

Evaluation done by:

____

Jim Immelt, one of the BESS originators, discusses the use of computers in the program with Evgeny Nesterov of the Pedagogical University of St. Petersburg, Russia.

I-1

We're Gettin' All Shook Up!

Background

In this lab, you will locate some of the world's major earthquakes and mountain ranges. You will then see how they are related to other features on the Earth. To accomplish this, obtain a map of the Earth that shows the crustal plate boundaries and volcanoes. Each position listed in the chart is a place where a major earthquake has occurred. On your map, write the letter identifying each earthquake at the stated longitude and latitude. The position given for each of the major mountain ranges is near the center of the range. On your map, write the name of each major mountain range, as near as you can, to the proper latitude and longitude.

Earthquake	Longitude	Latitude
A—China	110°E	35°N
B—India	88°E	22°N
C—Pakistan	65°E	25°N
D—Syria	36°E	34°N
E—Italy	16°E	38°N
F—Portugal	9°W	38°N
G—Chile	72°W	33°S
H—Chile	75°W	50°S
I—Equador	78°W	0°
J—Nicaragua	85°W	13°N
K—Guatemala	91°W	15°N
L—California	118°W	34°N
M—California	122°W	37°N
N—Alaska	150°W	61°N
O—Japan	139°E	36°N
P—Japan	143°E	43°N

Mountain Range	Longitude	Latitude
Himalayas	75°E	30°N
Alps	10°E	45°N
Atlas	0°	30°N
Appalachian	80°W	40°N
Andes	70°W	30°S
Coast	120°W	40°N

Questions

1. Describe the general relationship between the earthquake regions and the crustal plates.
2. Describe the general relationship between the mountain ranges listed and the crustal plates.
3. How are the positions of the earthquakes, volcanoes, and mountain ranges related?
4. Are all the earthquakes listed found along the edges of crustal plates? Why or why not?
5. Are all the mountain ranges listed found along the edges of crustal plates? Why or why not?

I-2

CHANGE

INTRODUCTION

Our world and universe are not the same from year to year, or even from day to day. Change is everywhere. Much of what interests scientists and much of what scientists investigate involves changes in one form or another—changes in the Earth and its organisms. Let's take some time to observe the changes that occur around us every day.

LOOKING FOR CHANGE

We cannot always be on hand to witness change; often, we must reconstruct events from clues left behind, like tell-tale fingerprints left behind at the scene of a crime. This process is known as inference. Unlike direct observations, inferences are conclusions based upon careful observation and data gathering. For example, if you saw a tree stump with bite marks on it, you might infer that a beaver cut down the tree. You can't say that with 100% certainty, because you didn't actually see the beaver bite through the tree trunk.

Inference is an important tool in science. Direct observation of specific events might be impossible during a scientific investigation; inference allows scientists to investigate tentative events from observed evidence. In this activity, you will use the scientific tools of observation and inference to gather evidence of change.

MATERIALS

- Notebook
- Camera (optional)
- Pencil
- Video Recorder (optional)
- Magazines (optional)
- Newspapers (optional)

PRE-INVESTIGATION ACTIVITY

Consider what the word **change** means to you. To help you do this, think about the following questions:

- When something is different from when you last observed it, what happened?
- How do you measure change?
- What do large differences over a short period of time indicate?
- What do small differences over a long period of time indicate?
- What are examples of things that do not change?
- What areas in our community are changing?

THE ACTIVITY

You may elect to do this activity by yourself or with one or two others. Investigate different areas for evidence of change. You might decide to use magazines or newspapers to gather evidence of change.

Identify as many different kinds of change as possible. Take careful notes and include evidence of the following changes:

- Changes that have occurred over long periods of time.
- Changes that have occurred over short periods of time.
- Changes that are caused by organisms.
- Changes that affected organisms.

If you decide to look around, you can make sketches of what you observe to share with your classmates. If you desire, you can take photographs or use a camcorder to record what you see and make a video tape to share with the class. If you decide to use photos from magazines and/or newspapers, mount them on some poster board to make a neat display.

The Presentation

Prepare a presentation for the class. In your presentation, describe the evidence of change that you have identified. Include the following information in your presentation:

- Describe how you know that a particular change has occurred during only a short period of time. Identify the force or forces that caused the change.
- Describe how you know that a particular change has occurred during a long period of time. Identify the force or forces that caused the change.
- Describe how you know that organisms caused a particular change (humans, other animals, plants or microbes).
- Develop some hypotheses to explain how populations of organisms might be affected by these changes.

Answer these questions on a separate sheet of paper ready to be turned in when you make your presentation:

1. When did you use inference in your investigation?
2. To what degree is the physical environment of our community changing?
3. How do environmental changes affect humans, other animals, plants, and microbes in our community? How do organisms change the environment?
4. If you could travel 10 years into the future, what changes would you expect to find in your community? What if you traveled 100 years into the future?

Western Center PLESE participants investigate changes in the Pawnee National Grassland of northeastern Colorado.

1-3

PLATE TECTONICS

THE PUZZLE OF THE CONTINENTS

Answer the following on separate sheets of paper.

1. Summarize three pieces of evidence that prompted Alfred Wegener to formulate his Continental Drift hypothesis.
2. How do oceanic plates and continental plates differ in their density? Explain the consequences of each of the following based upon your answer. Use diagrams.
   a. Collision of two continental plates.
   b. Collision of two oceanic plates.
   c. Collision of a continental plate and an oceanic plate.
3. What techniques did scientists use to demonstrate the presence of extensive mountain ranges beneath the ocean?
4. What evidence have scientists collected to verify that seafloor spreading has occurred?
5. There are three types of boundaries between plates. Name each type, explain the type of movement occurring at the boundary, and give an example of a locale where each type of boundary exists.
6. What kinds of plate interactions do you think may have caused the following earthquakes:
   a. San Francisco (1906 and 1989)
   b. Tokyo (1923)
   c. Anchorage (1964)
   d. Mexico City (1985)
   e. Northridge–Los Angeles (1994)
   f. Kobe (1995)
7. Explain the origin of island arcs like the island chain of Hawaii.
8. The rates of movement along plate boundaries have a range of 1 to 10 centimeters per year. Assuming the average rate of spreading along the Mid-Atlantic Ridge is 5 centimeters per year and knowing that the average distance across the Atlantic Ocean is about 5,000 kilometers, calculate how many years it has taken the Atlantic to open to its present position.
9. Using the same rate of spreading in question #8, determine how long it will take for the cities of Los Angeles and San Francisco (now separated by 650 kilometers) to join along the transform boundary of the western edge of the North American plate.
10. Assume that spreading rates are the same as in question #8, use a map of the world to predict how the positions of continents and shapes of oceans might change over the next 100 million years if:
    a. divergence continues along the Red Sea and the Gulf of Aden.
    b. a new plate boundary is created where the southern Atlantic Ocean begins to subduct beneath the east coast of South America.
    c. the African Plate pushes northward into the Eurasian Plate.
    d. rifting along the Gulf of California extends northward.
11. Do you think that there is any connection between the development and understanding of the theory of plate tectonics and the rapid advances in remote sensing technology over the past 30–40 years? Explain.

J-1

Jurassic Park Activity

Now that you have read *Jurassic Park* in its entirety, you have several options to select from for this project. Choose one of the options, carry out the project, and be prepared to turn it in on the due date.

1. Choose one of the **scientific/technological concepts or objects** from the novel and write a report on it. Some possibilities would include genetic engineering, CD-ROM technology, electric vehicles, etc. Your report should be word processed, at least four pages in length, and include your references. Be prepared to give a short oral presentation on your topic.

2. **Build a diorama or model** of Isla Nublar and Jurassic Park based upon the descriptions in the novel. You can select whatever medium that you want for your model (plaster, paper–mache, clay, wood, paper, etc.). Let your creativity run wild!

3. Prepare **an oral and a written report** on one of the **species of dinosaur** found in Jurassic Park. This report could be accompanied by laser–video disk images of dinosaurs available through the library. Alternatively, you might want to build a model of your dinosaur or make a poster. Your written report should be word processed, at least three pages in length, and include references. You could even elect to do a HyperCard Stack (maybe even with authentic dinosaur sounds?)!

4. Prepare an **oral and a written report** on one of the scientific **careers** mentioned in the book. Your report should include the kind of education and/or training required for the career you selected, as well as a thorough discussion of what an individual engaged in this career actually does. Your written report should be at least three pages in length, be word processed, and include references. One or more graphics should accompany your oral report. Another option would be to do your report on HyperCard!

5. **Design a game based on the novel.** It could be a board game, maybe tracing the route of Lex, Tim, Grant, Malcolm, and Regis on their ill–fated trip through Jurassic Park. You might want to make the game board into the shape of the island. Let your imagination take over!

6. Geologic history is punctuated by many extinction events. **Write a three–page paper exploring one of the theories relating to mass extinction.** You might want to focus on the sudden disappearance of the dinosaurs at the end of the Cretaceous era, since the novel you just completed deals with dinosaurs. Make sure that you cite at least four references. Be prepared to give a brief oral report on your paper.

7. **For those of you who are into philosophy and ethics, who, in your estimation, was the greatest villain in the novel?** Write a four–page paper, citing at least three pieces of evidence to support your claim. Be prepared to give a brief oral presentation defending your choice.

8. Can't find anything you like? You can contract with your instructor to do something else based on ***Jurassic Park***. It's up to you!

Rosanne Fortner, BESS Advisor and student parent, sized up a dinosaur bone at the museum at Dinosaur National Monument in northwestern Colorado.

J-2

MUTATIONS AND MISCONCEPTIONS

INTRODUCTION

How do you feel about releasing genetically engineered mutant organisms into the environment? Do you understand why it is so difficult to control a virus, such as AIDS, that is continually mutating? You need to come to a clear understanding of the terms mutant and mutation if you are to make informed decisions about your life.

BACKGROUND

The types of mutations you will be looking for are those that are called spontaneous. These are mutations that occur during normal cell reproduction due to errors in DNA replication, rather than resulting from large doses of radiation, cancer-producing agents (carcinogens), or other chemicals that cause mutations (mutagens). These latter types are called induced mutations. Mutagens simply increase the frequency of mutation events over the spontaneous rates of mutations that occur in nature. Spontaneous mutation rates range from about 1 in 1,000,000,000 (1 in 10^9) to 1 in 1,000,000 (1 in 10^6), whereas induced mutation rates occur at a greater frequency, from 1 in 1,000,000 (1 in 10^6) to 1 in 1,000 (1 in 10^3).

In this lab, you will be looking for spontaneous mutations conferring resistance to the antibiotic, streptomycin.

PROCEDURE

Day One: Starting the culture

1. Obtain a petri dish with solidified culture medium from your instructor. Make sure that the culture medium is free from any contaminating bacteria or fungi.
2. Using good aseptic technique, transfer a drop of the soil slurry to your culture dish by the conventional plate streaking method.
3. Turn the plates upside down and let them incubate at room temperature.

Day Two: Setting up a purification plate

1. Check your plate. Select a colony of bacteria for further study. Avoid using too much of the bacterial colony for streaking onto your second agar plate. Use just enough sample (termed the inoculum) so that it is visible on the loop. Even though it appears that you aren't using enough material, there are several thousand organisms that will provide more than enough material for the purification step.

Day Three: Establishing a broth culture

1. Take a slightly larger sample from a well-isolated colony on the purification plate and transfer it to a broth culture. Incubate for 24–48 hours. Check the tubes each day. The tubes will become cloudy (turbid), indicating the establishment of a bacterial colony. Tap the bottom of the tube with your forefinger to agitate the sedimented bacteria.

Day Four or Five: The Minimum Inhibitory Concentration (MIC) Test

1. Obtain a gradient plate from your instructor. This plate has an antibiotic incorporated into it along a concentration gradient.
2. Take a loopful of the test bacterium broth and use it to inoculate the surface of the gradient plate. Do this by streaking in a single line from the 0 µg/mL edge of the plate to the other side. Up to four individuals may use the same gradient plate being careful not to mix their streak into others on the plate and also being careful to keep track of which streak belongs to who.
3. Mark arrows on the bottom of the plate in the direction of the gradient (zero to maximum) to use as a guideline. Number the arrows for reference. Incubate the plates upside down.
4. Transfer a small sample from your broth culture to an agar slant to serve as a stock culture. Inoculate the slant by carefully "zig-zagging" the inoculating loop across the surface of the agar slant. Be careful not to cut into the surface of the agar slant. Incubate the agar slant.

Results

When growth appears on the gradient plate, it will form a continuous path up to the point that approximately represents the minimum inhibitory concentration (MIC). Then, the growth will end. Determine the MIC by measuring, along the diameter of the plate, the distance from the 0 µg/mL edge to the point where the bacterial growth ends, and dividing that distance by the total distance from the 0 µg/mL edge to the maximum concentration mark. Since the concentration of the antibiotic is linear, take the resulting value and multiply by the concentration of the antibiotic provided to you by your instructor.

Questions

1. What did your results show? Describe what your streak on the gradient plate looks like.
2. What is the significance of a culture where bacteria grow all along the antibiotic gradient?
3. What might the significance be of a culture in which bacterial growth stopped at a certain point along the gradient and then resumed further along the gradient?
4. Do you have a plate that displays this type of pattern? If you do, you should repeat the experiment with a fresh broth culture of the mutant.

Significance

1. What is a mutant?
2. What are some different types of mutations? How do they differ?
3. Why do physicians use different antibiotics to treat different diseases?
4. Why do some antibiotic treatments for bacterial infections sometimes fail?

BESS teachers Kim Bilica, Cindy Papp, Vince Trombetti and Don Hyatt discussing the BESS Program with teachers attending an NSTA Regional Convention.

J-3

SIMLIFE PROJECT

INTRODUCTION

Now that you have mastered the SimLife Tutorial and have had the opportunity to study natural selection, it's time to design an investigation on your own. Here's the scoop. Your group should decide on an investigation using the list of possibilities below, or, you can come up with an investigation on your own. Take a look at all the variables and parameters that you can control with SimLife! Literally, the sky is the limit for this one! It would be best to just look at one or at most a few factors in your design—if you don't, you run the risk of getting bogged down, as things will get very complicated very quickly.

You will be asked to explain the whys and wherefores of your investigation to the class and to describe and interpret the results in a short presentation. Each group will have around 5 to 10 minutes to do this, so get designing and simulating! A good way to do this would be to use graphs and/or charts showing your findings. You will be expected to turn in your investigation saved on your computer disk and turn in the completed data sheets which you will be provided with. **Your group should also turn in a written proposal of what you intend to do by the end of class.** You will have class time to set up your investigations, run them, and collect data for two days.

There are an unlimited number of investigations you can design and run with SimLife. Here are just a few ideas to get you started.

SEED–EATERS AND PLANTS

Design an investigation to see if, on the whole, seed-eaters do more damage or good to plant populations. Things to keep in mind:

- Many seeds don't sprout if they don't have the right genes for sprouting temperature and moisture.
- Seeds that don't sprout take up room that could otherwise be exploited by seeds that do sprout.
- Seeds that are eaten never sprout.

THE BATTLE OF THE SEXLESS

Design an investigation that shows whether or not sexual reproduction (as opposed to asexual reproduction) provides an advantage to a species. Keep in mind:

- The vast majority of species on Earth use sex during reproduction to expand their gene pool.
- Sexual reproduction requires the large energy expense of finding and courting a mate that could otherwise be used to find food or directly increase the population.
- What is there in the real world that's missing from SimLife that might make your results different?

OTHER WORLDS

A food web that is successful in Earth–like surroundings might not do as well if transplanted to another planet with different gravity, different ocean viscosity, and/or different energy returns from food sources.

Design an investigation that simulates another world, set loose some life, and see what happens. Then determine the genetic changes that would allow the life to better survive in the new surroundings. Things to remember:

- Different types of worlds can be designed in the Laws of Physics Window.
- It will be easier to start with food webs that have been proven survivors in an Earth–like setting.

GALAPAGOS

The Galapagos Islands contain the best known examples of divergent evolution because of isolation. Design an investigation where two populations (one on the mainland, one on an island) are isolated from each other, and see if and how the paths that evolution follows in the two populations differ. Keep in mind:

- To get the full effect, and to have different evolutionary pressures, make the mainland large, and the island small.
- Barriers over land or water will block walkers, but not fliers. To keep flying creatures from crossing the ocean, spreading their genes and messing up the investigation, have the island as far from the mainland as possible, and set the energy requirement for flying so high that an animal will starve to death before it can cross the ocean.

Pig Out

Sometimes colonists bring animals from their old homes to new lands. Unfortunately, these animals usually escape, and often don't have any natural enemies to keep their populations down. A classic case is the pig in Hawaii. It not only has no natural enemies, but also eats many of the native plants down to the roots, killing them.

Design an investigation to simulate the destruction done by pigs in Hawaii, and try to come up with a solution to the problem. Remember:

- Setting the food value of the plants too low in the Laws of Physics Window will cause herbivores to eat the entire plant and not just graze on the leaves.
- Sometimes solutions to problems cause their own problems, which are often even worse.

Cry Wolf

You may have read the book *Never Cry Wolf* by Farley Mowat or have seen the Disney movie based on the book. If you have, you know of the importance of the balance between the populations of wolves and caribou.

Design an investigation with a stable cyclic balance between wolves (carnivores) and caribou (herbivores), then go hunting and drastically reduce the wolf population. See if reducing the predators is better or worse for the prey. Keep in mind:

- Watch the Population Interaction Window first for establishing the stable wolf/caribou relationship, then keep watching to see the results when the wolf population drops.

Inbreeding

What happens when there is not enough genetic diversity within a species' gene pool? An April 1992 *National Geographic* article told of the modern day woes of lions living in the Ngorongoro Crater in Tanzania with just this very problem.

Design an investigation where a species with very little genetic diversity faces a new environmental pressure such as dwindling food source, climate change, or a new predator.

The California Water Rush

For the past 5 years, California has been suffering from a drought. Yet farmers still grow crops that require huge amounts of water and homeowners want nice rich, lush, large green (thirsty) lawns.

Design an investigation where you have many water-hungry plants flourishing in a wet environment, then slowly start to dry things up. See if you can develop new strains of the old plants that require less water, or come up with new plants that will meet the same needs without requiring the same amount of water.

Independent Project

Examine the list of all the changes you can do with SimLife. All of these changes can be potentially used in a SimLife investigation. Formulate a hypothesis, "If X changes, then Y will happen." All of these Changes for SimLife can be used as Xs in your hypothesis. Remember, it is best to choose one factor to change per investigation, so you can be sure which change you made caused what change in the results, a prerequisite of good investigational design!

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